OPTIMIZING RESOURCE UTILIZATION IN BEEF CATTLE OPERATIONS: REDUCING HAY WASTE, IMPROVING THE VALUE OF ROUGHAGE, AND PRESERVING INTEGRITY OF RATIONS

A THESIS

SUBMITTED TO THE FACULTY OF THE

UNIVERSITY OF MINNESOTA

BY

KATIE LYNN NENN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

ALFREDO DICOSTANZO

DECEMBER 2017

ACKNOWLEDGMENTS

First and foremost, I would like to thank by advisor, Dr. Alfredo DiCostanzo. I want to thank you for accepting the wild challenge of taking on a Crookston graduate and I can't thank you enough for the endless opportunities you have presented me with. I want to say thank you for your continued support through all of my experiences and research here at the University of Minnesota. You have not only helped me further my education, but also have helped further my experiences with employment upon graduation. You have been a great mentor to me during my graduate career at the University of Minnesota and for that I am grateful. I would also like to thank my committee members Dr. Eric Mousel, Dr. Mary Raeth, and Dr. Craig Sheaffer for kindly putting forth their time and effort to be on my committee, and for their insightful knowledge and encouragement throughout my time here at the University. Without all of your support I would not have been able to successfully complete by degree.

I would like to thank my fellow graduate students, the amazing people on the University of Minnesota Beef Team, undergraduate students, and the entire faculty at the University of Minnesota for all the wonderful memories and contribution to my success during my experiences in graduate school. I cannot thank you all enough for all of your time that you have helped me with my research projects. I have created some lifelong friendships that I am so grateful for, and thank you for making my experience here at the University of Minnesota amazing!

Lastly, I would like to thank my family that has supported me through my time here while in graduate school. You have all taught me the value of goals and how important it is to never give up on what you are passionate about. Without your kind

words of encouragement, I would not be where I am today and I thank you all for that. To my grandparents who have been my number one supporters I want to thank you for pushing me to pursue by dreams and always giving me your full support. I love you both so much and am grateful for everything you have done to help me have the best future possible! To my dad, I cannot thank you enough for showing me the true meaning of working hard and to never give up. You have always taught me that the best things in life don’t come easy, and every day I remind myself that. Thank you for always giving me your full support through every decision I have made. Thank you!

ABSTRACT

Rising prices of roughages and grains lead producers to constantly re-evaluate their feeding methods. Feed waste during storage, transfers, diet mixing and delivering is often underestimated or ignored. Concurrently, forages and forage quality are important to achieve production objectives, and sufficient profits. Feed costs are associated with forage quality because typically the higher the nutrient value the more expensive a feed source is. Reducing input costs, maintaining healthy livestock all while making a profit can be a challenge for many livestock producers in the Midwest. Thus, three different experiments were conducted to optimize resource utilization. The first experiment was conducted to evaluate forage waste when beef cattle were fed using three feeding systems. Systems evaluated were pull-type self-feeder, conventional bale ring and fence-line bunk. In this experiment, using a pull-type self-feeder led to less feed waste than feeding through a conventional bale ring or fence-line bunk. Experiment 2 was a backgrounding study with lightweight steers to evaluate growth performance effects of dry lot feeding corn stover untreated (CON), corn stover treated with an alkaline treatment (calcium hydroxide; TCS), corn stover hydrated with water (TWS), or grazing cattle on a cover crop (radishes and turnips; CC). Dry lot treatments were fed for 49 d followed by 64 d during which steers were fed a common backgrounding diet. Cattle grazed a cover crop for 29 d and then were fed the same backgrounding diet for 85 d. Following the common backgrounding period, cattle from all treatments were fed for 176 d on a common finishing diet. Feeding TCS resulted in intermediate rates of gain that were similar to those of cattle fed TWS or CON. In situ determination of DMD led to observations that, numerically, TCS had greater DMD (43.49%) and NDFD (54.82%)

than cattle fed CON or TWS at 48 h (31.02%, 39.50% and 18.99%, 22.17% respectively). At harvest, cattle fed CON had larger ($P = 0.03$) LM area than cattle fed either TCS or TWS. Cattle fed TWS tended ($P < 0.06$) to have less 12th rib fat depth than cattle fed TCS. There were no differences in other carcass characteristics between treatments. Results from this experiment demonstrated that treating corn stover with only water may be used to enhance low quality roughages albeit at higher DM intakes. A third experiment was designed to determine the effect of supplement type precision and accuracy of delivery. Findings from this study demonstrated that supplement form affected concentrations of DM, CP, Ca and Cu delivered to the bunk. Concentrations of DM and CP were closest to reference values when LS was used but those of Ca and Cu were closest to reference values when DS was used. Results from this study demonstrated that concentrations of Zn moved further away from the reference value as the mixer approached the end of delivery sites. Through this short-term study, we have demonstrated that supplement form and, for micro-minerals such as Zn, delivery order may impact nutrient concentrations in bunk samples.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

REVIEW OF LITERATURE

Forage Waste Based on Feeder Type

Introduction

Feed waste is often underestimated or ignored in raising beef cattle. Feed can be wasted due to contamination of the feed, weather, and by the type of feeding and delivery system being used (Landblom et al. 2007). Feeding hay to beef cows through winter months when pasture is not available (Miller et al. 2007) results in greater feeding costs. Hay may be processed or fed whole utilizing a feeder, or no delivery method at all. Supplemental feeds such as higher quality forages or grains are also sometimes required by beef cattle during this time.

Hay Delivery Methods

Choice of hay feeder type is dependent on region, cost, herd size, facilities, and equipment. One of the most common systems used to deliver hay to beef cattle is putting a large round bale in a conventional hay ring. Unfortunately, this system may lead to greater expense due to waste. Loerch (1996) reported the cost for hay fed ad libitum as round bales may reach $1.50 daily per cow or more. In addition, Belyea et al. (1985) and Baxter et al. (1986) found that using a hay ring can ultimately lead to 20 to 30% of the DM lost by feed waste.

Another common feeding method is rolling large round bales on a surfaced or un-surfaced area. Feeding hay on the ground is convenient and easy. Yet, cattle may trample hay or it may become contaminated with manure and urine (Hoffelt, 2011). Feeding hay on the ground resulted in 60% loss of the feeding value due to increased selection, contamination, and trampling (Hoffelt, 2011). Similarly, Rasby (2015) reported that feeding large hay bales without a feeder resulted in losses exceeding 45% of the DM. However, hay feeder design impacted hay loss; hay waste approached 30% with a hay ring (Hoffelt, 2011) or 11.4% when pull-behind feeders (Buskirk et al., 2003) were utilized.

There are a few advantages and disadvantages to each hay feeder based on design. Loss from feeders built with solid bottom panels were reported to lose on average 6% of the hay (Rasby, 2015). Buskirk et al. (2003) evaluated four types of hay delivery methods using non-lactating, pregnant beef cows. The four bale feeders used in that trial were hay ring, coned- hay ring, trailer, or cradle feeder. Alfalfa and orchardgrass round bales were fed ad libitum; average hay waste was 3.5%, 6.1%, 11.4%, or 14.6% for the coned hay ring, ring, trailer, or cradle feeders, respectively (Buskirk et al., 2003). Differences in hay waste were attributed to shape and how cattle accessed feed. Cattle behavior at the feeding area influenced feed waste (Hoffelt, 2011). Buskirk et al. (2003) discovered that cattle eating from a coned or conventional ring consumed forage as in grazing whereas cattle eating from a trailer or cradle consumed forage while keeping their necks level with the ground, which may have contributed to the amount of waste in those feeders.

Impact of Weather

In the upper Midwest, precipitation occurs in any of the four seasons. Spring and summer months can be humid, hot, dry, or wet and rainy. This can make it difficult to maintain fresh hay during storage, and at the feeding site. Hoffelt (2011) reported that hay nutrients leach if hay is not stored properly. Reduction of hay nutrients is caused by oxidation of nonstructural carbohydrates and mold growth (Coblentz et al., 2000). Lechtenberg et al. (1974) observed that large round grass hay bales stored in stacks outside for 6 months lost 8.2 % to 12.6% of its total DMD due to weathering. Investment in a storage method for harvested feeds is necessary to preserve forage nutrients. The initial cost of storage may seem expensive; however, net return includes reduced DM and nutrient loss.

Feed should continue to be protected from weathering once it enters the feeding site. Protection can include covers, side panels, and even trays. However, there are few bale feeders with any type of protection from weathering at the feeding site. Choosing a feeder that is made from metal and heavy duty will withstand massive winds more than a plastic feeder. Feeders with metal plates (cone feeders) on the top and bottom can provide more protection for feedstuffs (Buskirk et al., 2003; Moore and Sexten, 2015). Using an outdoor fence-line bunk to feed forage can be a disadvantage for producers because there is little to no protection from the environment. The only alternatives to managing weather effects on hay fed outdoors relate to timing of feeding and bale placement to prevent excessive weather impact on hay quality. Weather impacts are always a concern when feeding harvested feeds; but with the correct management practices, feedstuffs can be preserved.

Importance and Economic Significance of Choice of Hay Feeder

There are various designs and types of feeders commercially available, but little or no information exists on amount of feed wasted relative to cost. The average ring bale feeder costs anywhere between $150 to $500 depending on the brand and construction material; other, more sophisticated designs cost twice these amounts. Landblom et al. (2007) completed a trial to determine the effect of hay feeding method on cow wintering cost. Their experiment was conducted each winter over a 3-year period. Three hundred sixty crossbred cows were allocated to one of 3 treatments consisting of feeding alfalfa and oat hay by rolling bales out on the ground, shredding round bales with a PTO-driven bale processor and placing hay on the ground, or delivering whole bales in a tapered-cone round bale feeder. Feeding hay using the tapered-cone round bale feeder was the most cost-effective per cow. This was due to reductions in hay offered, equipment cost, and length of feeding time (Landblom et al., 2007). These findings suggest that a tapered-cone round bale feeder would be the most economical winter feeding method rather than feeding on the ground processed or not.

Choosing a hay feeder based on cost may not always be the best decision from an economic standpoint. Buying a lower-end quality hay feeder may be inexpensive at the time of purchase, but it can ultimately cost a producer more in feed waste. Wells and Lalman (2011) compared 4 common hay feeder designs: 1) modified cone 2) open-bottomed steel ring, 3) polyethylene pipe, and 4) sheeted-bottom steel ring. Based on results of their study, they projected and calculated the value of hay waste using these assumptions: 30 cows need 180 544-kg hay bales ($70/bale) each during a 6-mo period. Using these assumptions led to the conclusion that delivering hay to cows using the modified cone feeder, sheeted-bottom steel ring, steel ring, open-bottomed steel ring and polyethylene pipe led to $667.80, $1,638, $2,583, and $2,646 waste, respectively (Wells and Lalman, 2011).

Improving Forage Quality with an Alkaline Treatment

Introduction

Quality of forage is defined as the extent to which forage has the potential to produce a desired animal response (Ball et al., 2001). Forages are required in ruminant diets as they maintain rumen health (gut motility, cud chewing, saliva production, and rumen mat), and provide excellent source of energy and protein. Low quality forages, such as crop residues, have more lignified cell wall (Klopfenstein, 1978). Feeding forages with highly lignified cell walls can lead to poor or negative animal response as rumen microbes are unable to break down lignin bonds, thereby reducing the number of nutrients derived (Klopfenstein, 1978). Enhancing forage quality of mature forages by chemical or mechanical means is an option to purchasing high quality forages, or using grains and grain by-products.

Fiber Constituents

Forage quality is dependent on species, maturity, environment, genetics, harvesting method, and storage (Oba and Allen 1999). Constituents of forage cell wall affect intake. Ball et al. (2001) found that, relative to legume species, slower rate of fiber digestion of grass forages resulted in lower voluntary intake. Thus, faster digestion rate permits greater intake of DM and nutrients (Ball et al., 2001).

Forage cell wall growth is divided into two phases (Jung and Allen, 1995). Phase one refers to primary cell wall growth, where the plant cell is increasing in size through elongation; secondary phase occurs when cell elongation ceases (Jung and Allen, 1995). In the first phase, pectins, xylans, and cellulose are deposited but there is no lignin deposition (Jung and Allen, 1995). In phase two, Terashima et al. (1993) described that plant cell wall thickens towards the inner edge, and deposition of lignin polymer commences. This thickening of cell wall occurs as plants mature.

Plant cell structure can be classified as either non-fiber carbohydrate or fiber carbohydrate (Jung and Allen, 1995). Non-fiber carbohydrate is made up of cell contents, which serve as reserve energy storage for plants. Non-fiber carbohydrates are further classified as monosaccharides, disaccharides, and starch which have a high rate and extent of digestibility (Jung and Allen, 1995). Fiber carbohydrates are found in the cell wall and middle lamella and are composed of hemicellulose, cellulose, and pectins. As maturity progresses, fiber concentration increases resulting in extended digestion time and reducing digestibility of the forage and intake.

There are two chemically analyzable fractions that describe fiber in the plant; neutral detergent fiber (NDF) and acid detergent fiber (ADF), both of which reflect fiber carbohydrates. Neutral detergent fiber measures the fraction of fiber that is insoluble in neutral detergents and is related to voluntary intake (Van Soest et al., 1991). Acid detergent fiber impacts digestibility in the rumen because this fraction represents the least digestible plant components—cellulose and lignin. Thus, forages with low ADF concentrations tend to be higher in energy (Rasby and Martin, 2015). Cell wall portions of the forage contained in the ADF fraction are made up of cellulose and lignin; however, lignin is not a carbohydrate. Lignin contains both hydrophilic and hydrophobic groups that form strong bonds with carbohydrates in the cell wall (Bjorkman, 1957).

Legumes vs. Grasses

Legumes are higher in quality than grasses, and this is due to legumes having less fiber (Ball et al., 2001) at a correspondingly similar stage of development. An illustration described by Blaser et al. (1986; Fig. 1) describes growth stages of grasses or legumes and their effects on forage intake and digestibility. The schematic illustration demonstrates that, as a plant matures, leaf and CP content declines. Concurrently, as plants mature, hemicellulose, cellulose, and lignin fractions in the cell wall increase.

Forage Enhancement with Alkaline Treatment

Crop residues are a common forage source in beef cattle operations. Crop residue consists of stalks, stems, leaves, and seed pods or heads. Corn residue is one of the most abundant agricultural residues in the United States; it consists of the stalk, leaf, husk and cob (Holtzapple and Kaar, 2000). Other low-quality forages typically fed to beef cattle include straws from wheat, barley, oats, rice, and residue from milo (Klopfenstein, 1978).

Low quality forage can be enhanced by chemical treatment or supplementation (Klopfenstein, 1978). There are four commonly used chemicals to enhance forage fiber digestibility: calcium oxide or calcium hydroxide, sodium hydroxide, ammonium hydroxide, and potassium hydroxide (Klopfenstein, 1978). Treating forages with alkaline products disrupts the lignocellulosic matrix to make the cell wall more readily available to the rumen microbes (Holtzapple and Kaar, 2000).

Using ruminally cannulated steers, Oliveros et al. (1993) evaluated intake and digestibility response when feeding corn stover treated with calcium hydroxide or calcium hydroxide and ammonia or urea. They found that steers fed corn stover treated with calcium hydroxide had higher organic matter intake; organic matter digestibility was greater for corn stover treated with calcium hydroxide than for untreated corn stover.

Cover Crops

Cover crops are mixtures of cool-season forages planted shortly after cereal grain harvest or intercropped with longer-season crops (Lardy and Anderson, 2009). These forages are planted to manage soil erosion and moisture, break up soil compaction, and to build soil organic matter. Cover crops may be used to graze young stock or mature cows, ultimately improving the quality of the crop residue (Mousel, 2012). There are several varieties of cover crops that can be used for grazing: annual grasses (ryegrass, Italian ryegrass, teff), summer annuals (sorghum, pearl millet, etc.), legumes/clovers (sweetclover, alfalfa, etc.), cereals (wheat, barley, etc.), and brassicas/broadleaf plants (turnips, canola, burnet, etc.; Mousel, 2012). Turnips are a good choice for grazing cattle due to their high nutrient concentrations (20 to 25% CP, 20% NDF, and 23% ADF) even after maturing (Undersander et al., 1991; Koch, 2015). Furthermore, turnips are lower in fiber, readily digested, and provide adequate concentrations of energy to the animal (Koch, 2015). However, turnips are not drought resistant (Kinder, 2004). Cattle can typically graze turnips 60 to 70 d after planting (Kinder, 2004; Koch, 2015; Lardy and Anderson, 2009). This would be an ideal time for producers to use a grazing program after weaning calves in the fall. Calves that are weaned can be moved to a pasture and begin grazing. If cattle are not used to these forages it is recommended that cattle be adjusted to these green forages.

Integrity of Feed and Ingredient Mix as Affected by Supplement Form

Introduction

The goal of using a total mixed ration (TMR) mixer is to minimize within- and between-batch variation in moisture, particle size, energy, protein, mineral and vitamin concentration (Oelberg, 2009). Variation in nutrient concentration within and across batches is dependent on loading sequence, mixer condition, load size, ingredient attributes, and impact of weather during loading. However, form of supplement (liquid vs dry) used may play a role in determining integrity of feed mix. Pritchard et al. (2015) found that choice of supplement form is based on previous experience, limitations of storing site, loading and mixing equipment, and perception of cost of nutrient delivery. Yet, effects of supplement form on nutrient concentrations within and across batches have not been researched and are not understood.

Factors Affecting Integrity of Dietary Mixes

Factors that have the potential to impact mixing quality of diets include load size, loading order, mixing time, mixer type and condition of mizer. Poorly mixed TMR mixes can negatively impact animal performance and health (Oelberg and Stone, 2014). Retaining consistency of nutrient concentrations between each batch mixed can be very critical particularly when multiple daily deliveries to each pen are required.

The two most common TMR mixers used are horizontal or vertical mixers. (Oelberg and Stone, 2014). Horizontal mixers commonly found include: 4-augers, mono-mixer (1 auger), 3-auger, reel-auger, paddle, and drum mixers, while vertical mixers include: single auger, dual auger, and a triple auger (Oelberg and Stone, 2014). Each mixer type has inherent advantages and disadvantages for mixing feed; however, how these affect integrity of the mix is dependent upon operator, characteristics of each feed ingredient, and condition of equipment.

Loading order of feed ingredients affects integrity of dietary mixes. Schuler et al. (2011) found that loading order should be roughage first, then corn, protein supplement, and lastly a wet co-product (if used). When loading corn as the second ingredient, the protein supplement can incorporate with corn thereby preventing clumps from forming with the roughage (Schuler et al., 2011). Adding the roughage first can also allow more time for the knives to break down the feedstuff and reduce the forage size to a proper length. It has been a common occurrence in the upper Midwest to mix feeds in the order of hay, ground corn, protein/mineral supplement, wet distillers grain, and then liquid (Oelberg, 2009).

Mixer maintenance is important to maintain proper mixing process. Augers, kicker plates, and knives should be checked often for any wear and tear. In a mixer with augers, augers are set at specific agitator clearances of 0.3 to 0.9 cm, as these clearances increase because of wear, mixer efficiency is impaired (Oelberg and Stone, 2014). Kicker plates are responsible for proper blending of the TMR but if they are worn out they cannot properly lift the TMR thereby creating a dead spot (Buckmaster, 2009). In addition, knives in either a vertical or horizontal mixer are responsible for processing roughage, and chopping up clumps of feed. If the knives in a mixer are dull, feed ingredients will not accurately mix and blend causing variation in nutrient concentration over a delivery (Oelberg and Stone, 2014).

Mixing time can affect the integrity of the feed ingredients in a TMR mix. Over mixing a TMR will reduce particle size of forages and under mixing a TMR will decrease ration uniformity across the bunk (Dahlke and Strohbehn, 2009). Heinrichs et al. (1999) analyzed replicate 15-L samples from the mixer exit chute at 4, 8, 16, and 32 min after mixing began and found that increasing the mixing time beyond eight minutes resulted in a lower fraction of particles longer than 18 mm. This study showed that the longer you mix the more uniformity in particle size will occur. In a similar study, the same results revealed using a TMR mixed with ensiled forages (haylage, alfalfa silage), the fraction particles that were greater than 27 mm was decreased by 50% and the fraction consisting of particles greater than 19 mm were decreased by 19% due to mixing time (Heinrichs et al., 1999). Under mixing will lead to less uniform rations and over mixing will lead to reduce particle size which may affect feed intake.

Form of supplement: Dry vs. Liquid

Form of mineral supplement, dry or liquid, used on a facility is mainly determined by what a producer already has available to them. The actual cost of the product will play a determining factor into which supplement should be used by a producer. The cost of the supplement will vary by region and availability of feed ingredients. Factors affecting cost of a supplement are costs of protein or energy. Price is important but other factors that should be considered are the cost of feeding the product, availability, consumption amount required to balance the ration, waste, salt and mineral content, and bunk space (Torell and Balliette, 2013). Whitlow et al. (1976) found that feeding dry protein supplements may potentially increase labor requirements. Ultimately choice of liquid or dry supplement is determined by the producer based on price, convenience, previous experience and types of feed ingredients.

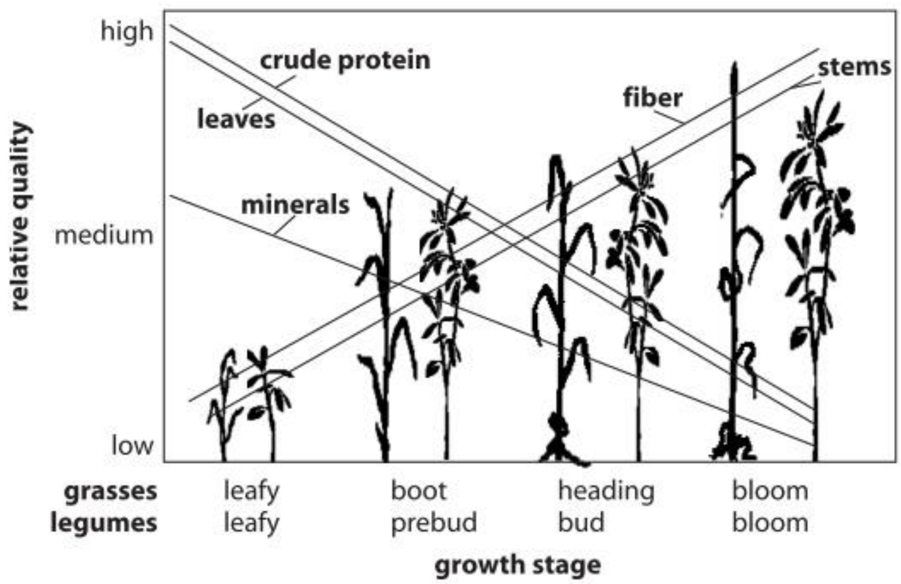

Figure 1. Effect of plant maturity on forage intake and digestibility (Blaser et al., 1986).

Chapter II

A COMPARISON OF FEEDER TYPES ON FORAGE WASTE BY BEEF COWS

K. L. Nenn, N. M. Kenney-Rambo, and A. DiCostanzo

University of Minnesota, Department of Animal Science, St. Paul, 55108

SUMMARY

Feed waste is an often underestimated or ignored cost in raising beef cattle. The impact of feeder type: hay ring (Ring), vs pull-type self-feeder (Wagon) or fence-line bunk (Bunk) vs Wagon on hay waste was measured in two trials utilizing Angus cows in late gestation in Trial 1 or early lactation in Trial 2, respectively. In Trial 1, 17 cows were permitted access to Ring or Wagon feeder over 8 72-h periods; 4 periods per feeder type in a switchback design. A large round orchardgrass bale was fed whole (Ring) or processed in a vertical Patz mixer (Wagon). Hay was delivered at 0900 h (0 h) and waste was collected at 24, 48, and 72 h. Soiled hay recovered outside the feeder was considered feed waste. Feed remaining in the feeder at 72 h was considered refused feed. In Trial 2, 18 cows were fed in Bunk or Wagon over 8 72-h periods; 4 periods per feeder type in a switchback design. The diet consisted of 64% alfalfa-orchardgrass hay and 36% haylage (diet DM). Feed was processed in a Patz vertical mixer for 20 min prior to delivery via either feeder type. Feed was adjusted daily for Bunk deliveries to be offered ad libitum with a minimum of refusals. Wagon deliveries were paired to feed amounts placed over 72 h in Bunk of the preceding period. Feed waste was collected at 24, 48, and 72 h for both feeder types and forage refused at 72 h. In Trial 1, feeding hay in Wagon reduced hay DM waste (4.0% vs 22.3% ±1.67 for Wagon and Ring, respectively). Similarly, forage DM waste in Trial 2 was 5.2% ±2.06 DM from Wagon while that from Bunk was 18.3% ±2.06 DM. Results demonstrated that placing ground hay or a combination of dry and high-moisture forage in a pull-type self-feeder of this design resulted in lower DM waste than when feeding hay in a ring or through a fence-line bunk.

Keywords: feed waste, beef cows, feeder

INTRODUCTION

Feed waste is an often overlooked or under-estimated expense. The cost of feed is the single largest variable influencing profitability of cow-calf enterprises in the Upper Midwest (Miller et al., 2001). Due to the length of winter and, consequently, short grazing season, cows are often fed harvested feeds in excess of 200 d per year. Harvested feed accounts for the greatest expense for cow/calf producers in the Upper Midwest (Buskirk et al., 2003). The causes of feed waste are varied but notably include exposure of feedstuffs to weather, contamination of feed with manure and urine, and trampling by animals. To minimize feed waste, it is a common practice to utilize a deliver it in a feeder or bunk.

There are a large number of feeders available commercially; hay rings of various designs tend to be the most common. In previous studies, it was found that feed losses may reach 20 to 30% of the DM fed due to feeding and storage methods such as outside or inside storage (Belyea et al., 1985; Baxter et al., 1986). Similarly, Kallenbach (2000) observed that feeding harvested forage to beef cows can cost on average $0.04 to $0.15 per kilogram of DM, and this is twice the cost for the same amount of nutrients derived from pasture. Feeding method (Landblom et al., 2007), method of storage (Belyea et al., 1985) and feeder design (Buskirk et al., 2003) influence the amount of hay wasted or refused by beef cows; however, environment exposure also effects feed waste. Environmental impact such as excessive rain, drought, or freezing temperatures can increase the cost of production for a cow due to forage availability, hay, and feed prices (Walker et al., 2013). Type of feeding system has the second greatest influence, following environmental impacts, on feed waste.

Landblom et al. (2007) found that feeding hay from a tapered cone feeder resulted in 4.3% to 5.0% less feed waste than rolling out or processing a round bale then delivering it onto the ground. As an alternative to pasture systems, cows may be confined to a dry lot for part or all of the year and fed from a bunk (Loy, 2010). With significant increases in feed costs producers seek alternative methods for feeding forage. The objective of these two trials was to determine effect of feeder (hay ring vs pull-type wagon or fence-line bunk vs pull-type wagon) on DMI and wasted feed DM.

MATERIALS AND METHODS

Forage Production

Hay was grown and processed at the Rosemount Research and Outreach Center in Rosemount, MN. There were 2 lots and types of hay produced for each of the 2 feed waste trials. First cutting crop hay used for Trial 1 contained Meadow brome; Bromus biebersteinii Roem. & Schult. (St. John et al., 2012) quackgrass; elymus repens (USDA NRCS Plant Materials Program, 2017), meadow foxtail; Alopecurus pratensis L. (USDA NRCS Plant Materials Program, 2017), and red clover; Trifolium pretense L. (USDA NRCS Plant Materials Program, 2017) and baled in June of 2015. Hay was baled using a conventional round baler (Model 569; John Deere Inc., Moline, IL) which produced 1.5 x 1.8 m large round bales. Second cutting crop hay fed in Trial 2 contained alfalfa; Medicago sativa L. (USDA NRCS Plant Materials Program, 2017 and orchardgrass; Dactylis glomerate L. (USDA NRCS Plant Materials Program, 2017) baled in early July of 2015. Hay was baled using a conventional large square baler (Model 100; John Deere Inc., Moline, IL) and produced 0.91 x 0.91 x 2 m square bales. Large rounds and square bales were removed from the field within 24 h of baling and moved to storage. Round bales were stored outside stacked side-by-side on unsurfaced areas, and large square bales were placed indoor for storage until fed. Haylage used in Trial 2 was harvested in May of 2015 using a self-propelled disk bine (Model 1411; New Holland., Vermillion, MN) and a forage harvester (Model 8400; John Deere Inc., Moline, IL).

Large round bales had a DM concentration of 84% determined by drying samples for 48 h at 60° C (Blue M Electric; Thermal Product Solutions, New Columbia, PA). Haylage contained 49 % DM as determined by drying samples for 48 h at 60° C (Blue M Electric; Thermal Product Solutions, New Columbia, PA); it contained 10.0 % CP as determined following the procedure of Ciriaco et al. (2015). Large square bales were tested by an outside lab (Dairyland Laboratories, Inc., Arcadia, WI); their nutrient concentrations were (DM basis): 88.7% DM, 16.8% CP, 45.3% ADF, and 55.2% NDF.

Trial 1

Seventeen Angus cows in their third trimester of gestation were used to evaluate the amount and percentage of forage consumed and lost from delivering hay using 1 of 2 types of feeders at the Beef Research and Education Complex facility located in Rosemount, MN. Conventional ring (Ring; CLF Wingert Sales, Plainview, MN) or a pull-type self-feeder (Wagon; Model Quad, Barron Built, Ruthton, MN) were evaluated. The amount of hay fed to cattle were determined by methods defined by Buskirk et al. (2003). Briefly, Buskirk et al. (2003) described that over a 7-d period, they only added hay to the feeder if intakes were potentially limited during the following 24 h. Cows were adapted to eating from each feeder type for 4 d prior to initiation of the trial. Bales placed into Ring were left unprocessed while those placed into Wagon were processed with a tractor (Model 6155R; John Deere Inc., Moline, IL) and vertical mixer (Model V420; Patz Corporation, Fairbault, MN) for 20 min prior to delivery. Cows were fed from a single feeder for a 72-h period in a switchback design with 4 72-h period replicates completed per feeder. Water was available at all times and a mineral lick tub was provided ad-libitum (Rangeland 30-13, Purina Animal Nutrition LLC, Shoreview, MN)

Trial 2

Eighteen Angus cows in early lactation were used to evaluate the quantity of forage consumed and lost from 2 different types of feeders at the Beef Research and Education Complex facility located in Rosemount, MN. The diet (Table. 1) consisted of 64% alfalfa-orchardgrass hay and 36% haylage (diet DM) delivered through 1 of 2 types of feeders: a 21-m fence-line bunk (Bunk; Fenceline Bunk, Wieser Concrete, Maiden Rock, WI; 21m long x 0.61 m wide) and a pull-type self-feeder (Wagon; Model Quad, Barron Built, Ruthton, MN; 4 x 2 m). Cows were adapted to eating from each feeder type for 4 d prior to initiation of the trial. Cattle were expected to consume 2.2% of their BW and feed was delivered accordingly (NRC, 2000). Large square alfalfa-orchardgrass bales were processed in a vertical mixer (Model V420; Patz Corporation, Faribault, MN) with a tractor (Model 6155R; John Deere Inc., Moline, IL) and mixed for 20 min with haylage before feeding. Cows were fed from a single feeder for a 72-h period in a switchback design with 4, 72-h period replicates completed per feeder. Water was available at all times and a mineral lick tub was provided ad-libitum (Rangeland 30-13, Purina Animal Nutrition LLC, Shoreview, MN)

Feeder size and space

Within each 72-h period, the corresponding feeder (Ring or Wagon) was placed on a concrete pad (30.5 x 6 m). This pad was bordered on the north side by a 21-m concrete bunk (Fenceline Bunk, Wieser Concrete, Maiden Rock, WI; 21 x 0.61 m), which was used in Trial 2 only. Ring was a 2.4 x 1.2 m polyethylene round bale feeder and, with 17 cows, it provided 14 cm of curvilinear feeder space per animal. The Wagon was 4 x 2 m feeder that provided 12 cm of linear feeder space per animal per head. The bunk was 0.56 m in depth on the delivery side and had a 0.43 m depth on the cattle side that provided 116 cm of linear feeder space per animal. A wind break shaped out of large round bales (1.5 x 2.1 m) stacked in one row of 2 bales placed on the south and west sides of the concrete pad.

Sample Collection

Samples were collected to determine the composition and amount of hay offered, refused, and wasted. Bales used in Ring were sampled immediately before feeding by placing a 0.61 m probe in the round bale and taking 20 core samples using a Forageurs hay probe (Forageurs Corp, Lakeville, MN). All forage samples were frozen immediately for later analysis. Round bales were individually weighed on a platform scale and bale twine was removed and weighed before delivering in Ring. Bales placed in the Wagon were processed in a vertical mixer (Model V420: Patz Corporation, Fairbault, MN) for 20 min before placing in Wagon. Wagon was weighed before and after loading the feed and the difference was taken to calculate the total amount of feed delivered for each trial. Hay was then delivered in the respective feeder and a 4-kg sub-sample was collected and frozen for later analysis.

In the second trial, alfalfa-orchardgrass bales were sampled by taking sections from inside and outside the bale until a 4-kg sample was obtained before loading the mixer. Haylage was sampled with the same process by taking multiple sections from the pile until a 4-kg sample was obtained. The tractor and vertical mixer were weighed before and after delivery on the platform scale to determine total amount of feed delivered. Once feed was delivered to the Bunk, a sample of the TMR was collected and frozen immediately for later analysis.

Hay refusal was any feed left inside the feeder at the end of the 72-h observation period. Hay waste was feed that was soiled, trampled, weathered contaminated, or out of reach and collected at 24, 48, and 72-h. Hay refusals and hay waste were collected in 114 L paper lawn bags (Home Depot, Forest Lake, MN) and weighed on a platform scale at the end of each 72-h observation period. Hay refusals from Wagon were weighed by difference on the platform scale. A 4-kg sub-sample for hay refusals and hay waste were collected and immediately frozen for later analysis for each 72-h observation period. The concrete pad was scraped clean after every collection time and 72-h observation period to minimize carryover from previous observations.

Sample Analysis

Prior to laboratory analysis, feedstuffs and hay refusal samples were dried (Blue M Electric; Thermal Product Solutions, New Columbia, PA) at 60° C for 48 h to determine DM. Samples were ground to pass through a 2-mm screen using a Thomas

Model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ). Hay offered, refused, and wasted samples were composited based on individual percentage of the total feed offered, refused, or wasted for each period.

All samples were analyzed for NDF (Van Soest et al., 1991) and ADF (Method 973.18; AOAC, 2000) on site. Neutral detergent fiber analysis was completed using the Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, MY), where samples were extracted for 60 min at 100° C in NDF solution with heat stable α-amylase. Following NDF analysis, samples were dried at 100° C (Thelco 130DM; Precision Scientific, Chicago, IL) then weighed and NDF percentage was calculated. Following the NDF analysis ADF was analyzed utilizing the same procedure as NDF. However, with the ADF procedure ADF solution was used and samples were extracted for 60 min at 100° C followed by drying overnight at 100° C, weighing, and then calculating ADF percentage.

Statistical Analysis

Feed disappearance was calculated as the amount of hay delivered to the feeder, minus the residual amount of hay remaining in the feeder at the end of the 72-h observation period (Buskirk et al., 2003). Hay waste percentage was calculated as the amount of wasted hay divided by feed disappearance (Buskirk et al., 2003). Hay intake was determined as the difference between hay disappearance and hay waste (Buskirk et al., 2003). Hay waste, hay intake, hay disappearance, and nutrient concentrations of hay delivered, refused and wasted were analyzed using the Proc Mixed procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). Feeder was the experimental unit. Response variables included hay waste, percentage of hay waste, hay disappearance, and hay DM intake which were analyzed for treatment effects. The model for nutrient data included sample type (delivered, refused, waste), feeder type, replicate, period, and their two-way interactions as independent variables. Effects were considered significant when $P < 0.05$ and a trend was considered with $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

The effect of feeder type on hay waste and intake for Trial 1 is shown in Table 2. There was a significant difference between feeder type and hay waste ($P < 0.05$) in Trial 1. Using a Ring resulted in nearly five times more hay waste compared to a Wagon. Buskirk et al. (2003) reported similar findings: feeding hay in a ring feeder resulted in nearly twice as much feed waste compared to a cone feeder. In contrast, Buskirk et al. (2003) observed greater feed waste from the trailer and cradle feeders, as compared to the ring feeder. Differences in wagon design may account for differences in waste between results reported by Buskirk et al. (2003) and those from the present study. The Wagon feeder used in this trial was designed to limit access to the entire feed supply at once; as they consumed hay from the stack of processed hay, it would fall from the next layer as room was made. In a similar study, DiCostanzo and Jaderborg (2015) compared a ring feeder or feed bunk to feeding on a pen surface and had opposite findings of less hay waste from a ring feeder or feed bunk. Compared to the findings in the current trial (Trial 1) feeding hay from a ring feeder had significantly more hay waste. In addition, there was a tendency for a lower feed intake with the Ring compared to the Wagon ($P < 0.06$). Similar findings from Buskirk et al. (2003) were observed between the ring and the trailer; 11.4 kg vs. 12.3 kg respectively. In contrast, DiCostanzo and Jaderborg (2015) observed higher feed intake from a ring feeder. These results may differ from the current trial because of weather conditions, cow size, and observations were over a 10-d period and hay was only replaced if needed. In the current trial hay was fed in a ring over a period of 72-h period

There were no significant feeder type effects ($P < 0.38$) for NDF on hay offered, hay refused, or hay wasted for Trial 1 (Fig. 1). However, there was a significant difference effect between feeder type for ADF on hay offered, hay refused and hay wasted ($P < 0.03$; Fig. 2). These results demonstrated that cattle could sort for higher quality feed when eating from the Wagon feeder. Bourquin and Fahey (1994) found that leaves of mature alfalfa and orchardgrass have a lower percentage of ADF than stems, so results from this study indicate that cattle may have consumed more leaves than stems from the Wagon. In addition, feed that was sorted in the Wagon feeder was left in trays that allowed the cattle to sort a second time.

The effect of feeder type on hay waste and intake for Trial 2 is shown in Table 3. There was a significant effect of feeder type on hay waste ($P < 0.05$) in Trial 2. Feeding a TMR mix from a Bunk resulted in four times greater feed waste compared to feeding from the Wagon. DiCostanzo and Jaderborg (2015) had similar findings; there was significantly more hay waste from a bunk. However, an energy supplement was added to the diet in that study. Comparatively, there was more hay waste from a Bunk recorded in this trial. In the present trial, a TMR mix based on high moisture forage was used. This may have led to greater feed waste in the current experiment. In contrast to results from the first trial, feed intake did not differ with feeder type ($P < 0.16$). This could be to the result of greater space available to access feed in Bunk.

There was a significant effect of feeder type on NDF content (n = 24) in hay offered, hay refused, and hay wasted in Trial 2 ($P < 0.01$; Fig. 3). These results are similar to observations made for ADF concentration in hay offered, hay refused and hay wasted (Trial 2). Hay offered may have had less moisture (higher quality) initially and over the period of 72-h hay may have gained moisture (lower quality) due to poor weather conditions. Aasen et al. (2004) found the difference in moisture content of a feed can affect quantity and quality of feed consumed by cattle. This too may be caused by the ability of cows fed from the Wagon to sort for higher quality hay. Similar to Trial 1 (Ring vs. Wagon), there was a significant effect of feeder type on ADF concentration in Hay offered, hay refused, and hay wasted in Trial 2 ($P < .003$; Fig. 4). Differences in ADF values of hay initially offered compared to hay refused and wasted may have been due to sorting for greater leaf and stem distinction in the TMR mix (Moore and Sexten, 2015).

Conclusion

Results from both trials demonstrated that feeding dry forage (ground hay) or a combination of dry and high-moisture forage in Wagon lead to lower DM waste than feeding dry forage in a Ring or a combination of dry and high-moisture forage in a Bunk. Using a conventional ring to feed large round bales is easy to use and relatively little labor it is needed. However, low labor input required may translate to greater feed waste as demonstrated by results in this study. Although feeding from a fence-line bunk may be ideal under the proper circumstances (denser feeds in climates with lower precipitation), bulk and density of feeds used in this trial led to greater feed waste and refusals. Using the appropriate forage feeding system for given moisture content, feed bulkiness, etc. is necessary because it can be cost-effective by reducing feed waste, but also because it creates the possibility of preserving forage.

Table 1. Dry matter composition of diets.

Ingredient	Diet DM, %
Trial 1	
Orchardgrass	84.0
Trial 2	
Alfalfa-orchard	64.0
Haylage	36.0

Table. 2 Effect of feeder type on daily forage dry matter (Trial 1).

	Feeder type		
Item	Wagon	Ring	SEM[1]
Hay intake, kg/cow[2]	10.4	8.8	0.48
Hay waste, kg/cow	0.4 [a]	2.6 [b]	0.17
Hay disappearance kg/cow[3]	10.8	11.4	0.41
Hay waste, %[4]	4.0 [a]	22.3 [b]	1.67

[1]Standard error of the least squares means.
[2]Hay disappearance minus hay waste.
[3]Hay fed minus residual hay at the end of the period.
[4]Hay waste as a percentage of hay disappearance.
[ab]Means within rows with different superscript differ ($P < 0.05$).

Table. 3 Effect of feeder type on daily forage dry matter (Trial 2).

Trial 2	Feeder type		
Item	Wagon	Bunk	SEM[1]
Hay intake, kg/cow[2]	10.8	9.2	0.73
Hay waste, kg/cow	0.6[a]	2.0[b]	0.26
Hay disappearance[3]	11.4	11.2	0.73
Hay waste, %[4]	5.2[a]	18.3[b]	2.06

[1]Standard error of the least squares means.
[2]Hay disappearance minus hay waste.
[3]Hay fed minus residual hay at the end of the period.
[4]Hay waste as a percentage of hay disappearance.
[ab]Means within rows with different superscript differ ($P < 0.05$).

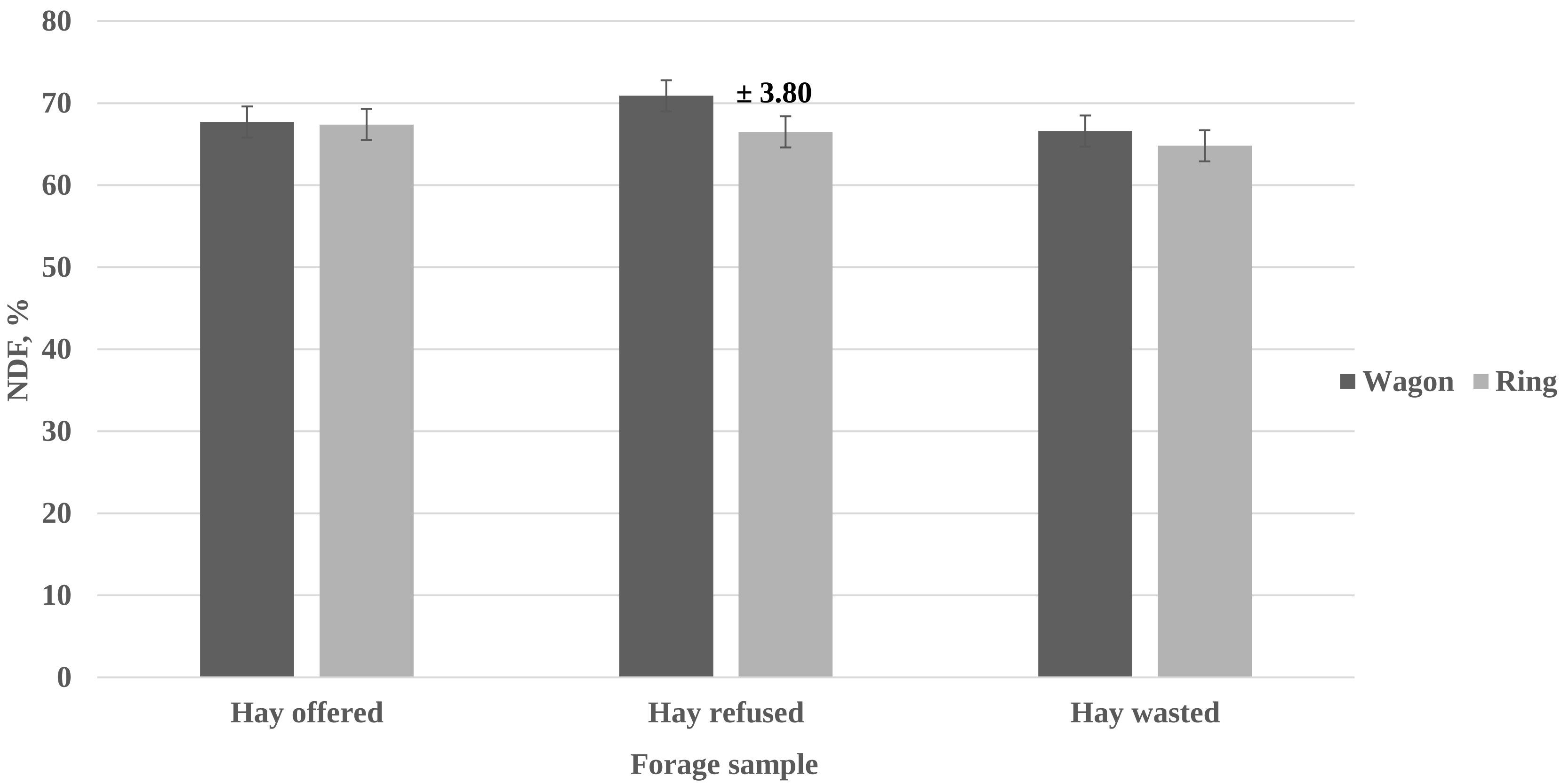

Figure 1. Neutral detergent fiber analysis of hay offered, refused, and wasted in Trial 1 (Ring vs Wagon). Feeder type did not differ ($P < 0.05$) for NDF analysis of hay offered, refused, or wasted.

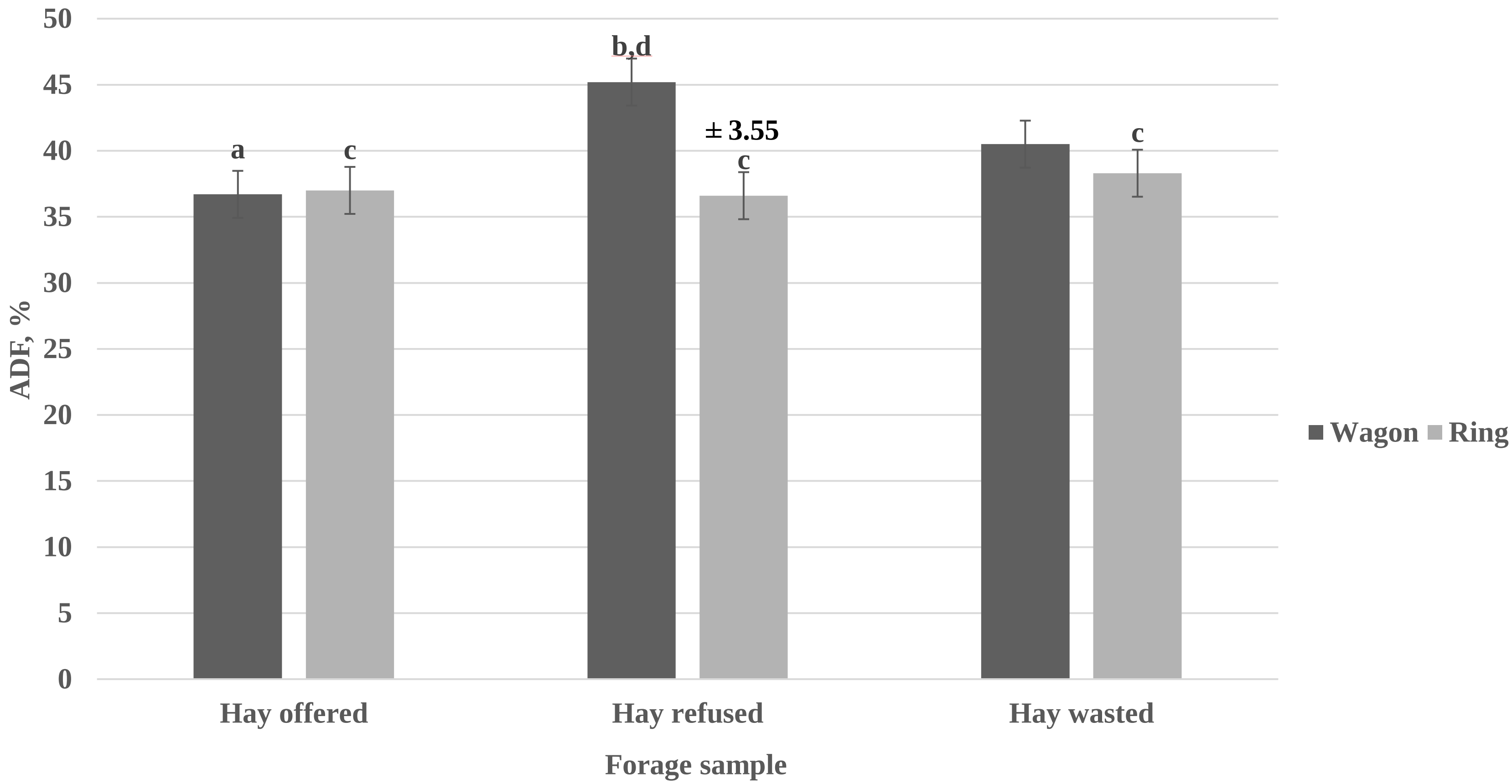

Figure 2. Acid detergent fiber analysis of hay offered, refused, and wasted in Trial 1 differed between feeder type (Ring vs. Wagon).
[abcd] Means with different superscript differ ($P < 0.05$).

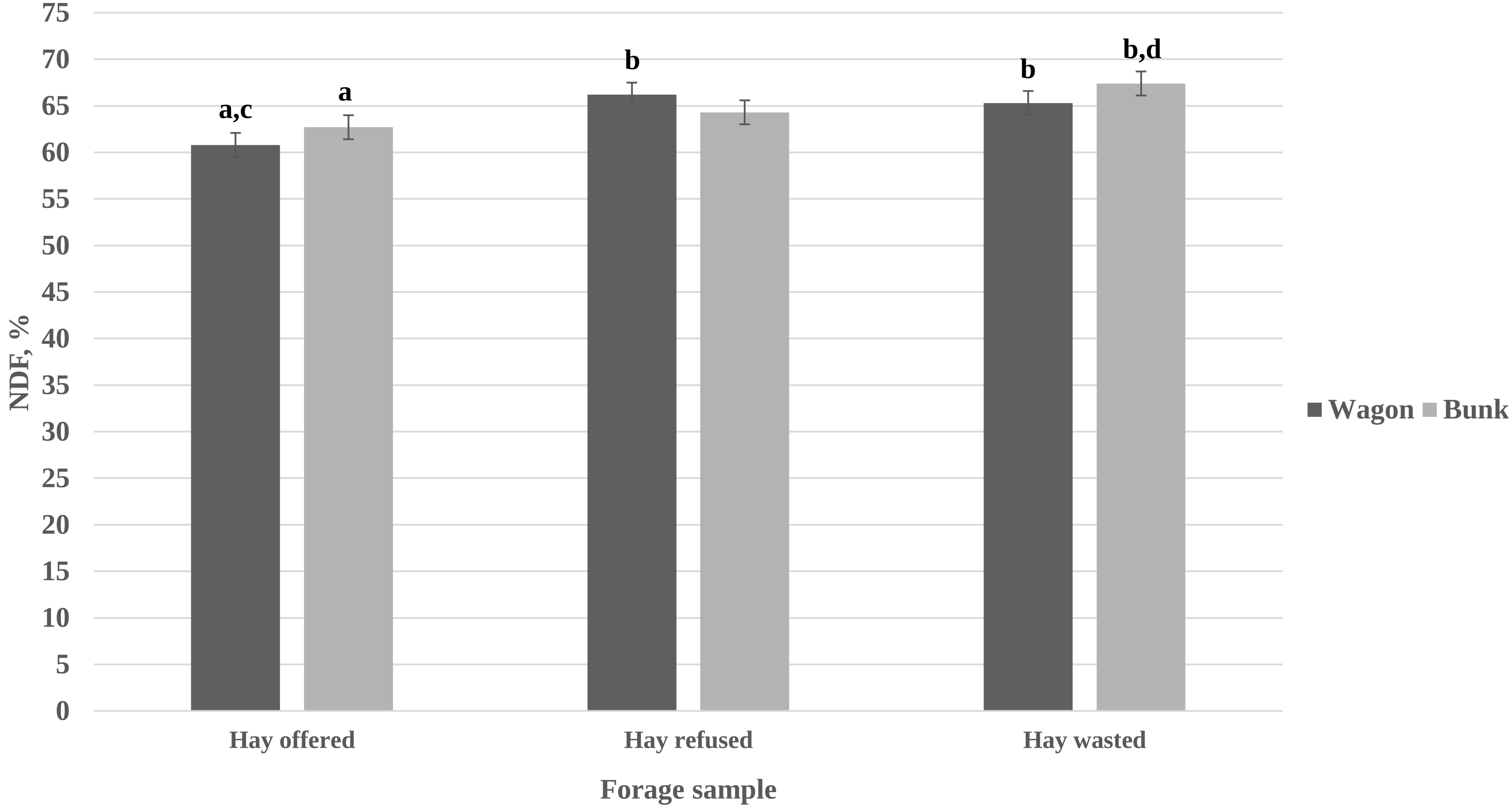

Figure 3. Neutral detergent fiber analysis of hay offered, refused, and wasted in Trial 2 differed between feeder type (Bunk vs. Wagon). [abcd] Means with different superscript differ (*P* < 0.05).

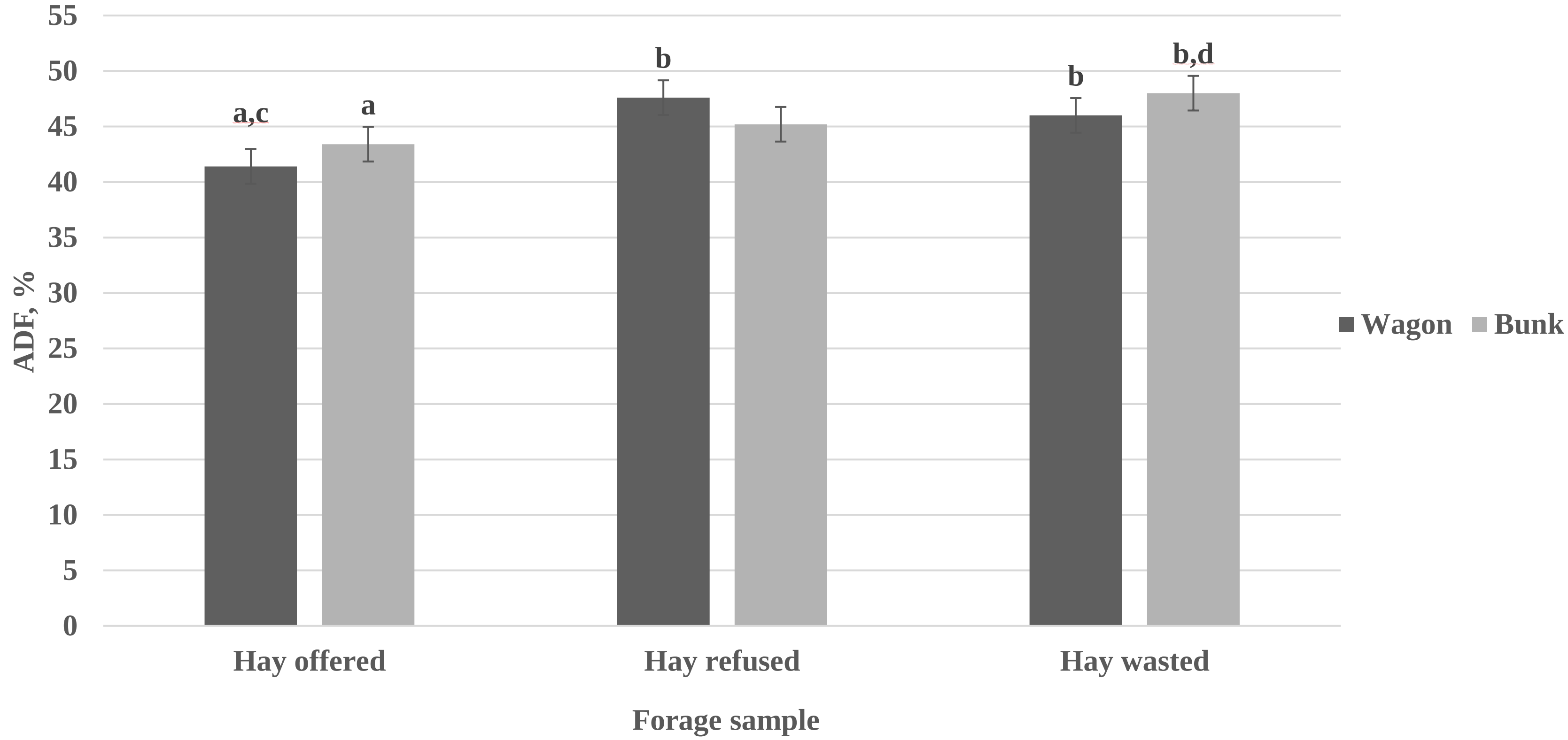

Figure 4. Acid detergent fiber analysis of hay offered, refused, and wasted in Trial 2 differed between feeder type (Bunk vs. Wagon). [abcd] Means with different superscript differ ($P < 0.05$).

Figure 5. Hay ring (Ring).

Figure 6. Pull-type self-feeder (Wagon).

Figure 7. Fence-line bunk (Bunk).

Chapter III

IMPROVING THE FEEDING VALUE OF CORN STOVER TO ENHANCE CATTLE PERFORMANCE IN A BACKGROUNDING PHASE

K. L. Nenn,* P. H. V. Carvalho,[†] E. Mousel,[§] G. A. Bridges,[§] S. Bird,[§] T. L. Felix,[†] and A. DiCostanzo*

[*]University of Minnesota, Department of Animal Science, St. Paul, 55108

[†]University of Illinois at Urbana-Champaign, Department of Animal Sciences, Urbana, 61801

[§]North Central Research and Outreach Center, Grand Rapids, 55744

SUMMARY

The objective of this study was to (1) investigate effects of 4 dietary approaches to backgrounding steer calves (initial BW 198 ± 10 kg) using water or alkali-treated corn stover or grazing cover crops on backgrounding calf performance, subsequent feedlot performance, and carcass characteristics, and (2) to investigate effects of alkali-treatment or water addition to corn stover on in situ DM and NDF disappearance (DMD and NDFD). During a backgrounding phase where calves were fed individually, corn stover (untreated) was fed at 30% of diet DM (1) control diet (CON), (2) alkali-treated with 6% (DM basis) calcium hydroxide (TCS), or (3) treated with water (TWS) to bring moisture content to same concentration as TCS; a fourth group of steer calves were permitted to graze (4) turnips seeded as a cover crop (CC). Fifty lightweight Angus steers were backgrounded in a drylot while 16 steers were placed on the CC treatment. Remaining ingredients of backgrounding diets were (DM basis) 15% alfalfa haylage, 25% dried distiller's grains with solubles, 25% dry rolled corn, and a 5% vitamin-mineral supplement. Steers were fed once daily at 0600 h and orts were collected and sampled. Shrunk live weight was obtained after withholding feed and water for 16 h on d 0, 29 (end of CC grazing period), and 49 (end of individual feeding backgrounding), and, subsequently, at the end of the common backgrounding phases (64 d TCS, TWS, and CON; 85 d CC). Shrunk live weights were not obtained at the end of finishing (176 d) phase. Interim BW was recorded every 28 d prior to feeding. In situ DMD and NDFD were measured at 12, 24, 36, and 48 h in 2 ruminally cannulated steers. There were no effects of treatment on DMD ($P = 0.13$) or NDFD ($P = 0.26$) statistically, but numerically there were differences. Cattle fed TWS consumed more ($P < 0.0001$) DM and had heavier BW ($P = 0.01$) than those fed TCS, CON, or grazing CC. Cattle fed TWS had faster ADG ($P = <0.0001$) than those fed TCS or CC; however, cattle fed CON had similar ADG ($P = 0.75$) as cattle fed TWS. Cattle on CC had lighter BW ($P < 0.0001$) at d 29 and 49. Carcasses from cattle fed CON had a larger LM area ($P = 0.03$) than those from cattle fed either TCS or TWS. Carcasses from cattle fed TWS tended to have less ($P = 0.06$) 12th rib fat depth than those from cattle fed TCS. Overall, results from this experiment indicate that feeding cattle TCS did not impact animal growth performance or carcass characteristics. Treating corn stover with calcium hydroxide effected no changes in DMD or NDF; indeed, cattle fed corn stover treated with water consumed more feed and had greater gains, albeit at lower incremental feed conversion, during treatment period. Because of no impact on subsequent gains or carcass quality, we proved that an alternative to backgrounding cattle on low quality forages may be simply grazing a cover crop.

Keywords: alkali-treatment, corn stover, in situ

INTRODUCTION

Corn stover is commonly used in backgrounding rations for growing cattle to provide an inexpensive roughage source. At times when forage prices are high, feedlot producers and cow calf operators need an alternative roughage source, such as crop residues, that is affordable. Corn stover may be an option, but it is low in energy and protein. Feeding corn stover may lead to low intake due to dryness and low palatability, and digestibility is generally below 50% leading to poor gains (Klopfenstein, 1978). Grazing cattle on crop residues supplemented with concentrates would be an alternative to harvesting and feeding it as this strategy saves costs of fuel, oil, labor, and equipment. Unfortunately, in many locations grazing cattle on crop residues is not possible due to agronomic reasons and weather (Gigax et al., 2011). Alternatively, increased cover crop applications in certain areas of the country may improve access by producers wishing to background lightweight calves on cover crops in the late fall.

Alkaline treatment of forages was researched in the 1970's as a method to improve forage quality at low cost. Recently, this method was re-evaluated (Cooper et al., 2014; Watson et al., 2015). There are 5 alkaline compounds that have been used to enhance the value of crop residue, these include: sodium hydroxide, ammonium hydroxide, potassium hydroxide, calcium oxide, and calcium hydroxide (Anderson and Ralson, 1973; Rounds and Klopfenstein, 1974; Waller and Klopfenstein, 1975; Solaiman et al., 1979; Klopfenstein and Owen, 1981). Treating low quality forage or crop residues alkali treatments was intended to increase rate and extent of cell wall digestibility by breaking the bonds between lignin and cellulose or hemicellulose (Klopfenstein and Owen, 1981). Specifically, Wanapat et al. (2009) found that calcium hydroxide broke ester bonds between lignin and hemicellulose thereby resulting in greater digestibility. Calcium oxide is an effective method to enhance the energy value of poor quality roughages (Klopfenstein, 1978); however, it is more caustic and difficult to store and handle. Calcium hydroxide is a hydrated lime that does not produce heat when mixed with water because it has already gone through this process when formed.

Recently it was discovered that soaking poor-quality roughages in water before ensiling resulted in greater energy value comparable to that resulting from treating and ensiling poor quality roughage with calcium hydroxide (Duckworth et al., 2013; Ndlovu et al., 1989). Water addition may be more practical due to reduced treatment cost and eliminating the need for handling chemicals on the farm.

Additionally, increased interest in utilizing cover crops to manage soil characteristics in crop growing areas may provide an opportunity to diversify crop and livestock operations by permitting grazing of cover crops by growing cattle or beef cows. Cover crops are used to manage soil erosion and moisture, break up soil compaction, building soil organic matter, grazing, and ultimately improving the quality of the crop residue (Mousel, 2012). The relatively low cost of establishment and the stimulation of compensatory gain in calves following grazing of cover crops may be another alternative to backgrounding calves in a drylot. Grazing growing cattle on cover crops such as turnips represents an alternative that has not been compared to the use of low quality roughages alkaline treatment during a backgrounding phase. Thus, we sought to (1) investigate effects of 4 dietary approaches to backgrounding steer calves including grazing cover crops on backgrounding calf performance, subsequent feedlot performance, and carcass characteristic and (2) to investigate effects of alkali-treatment or water addition to corn stover on in situ DM and NDF disappearance (DMD and NDFD).

MATERIALS AND METHODS

All procedures used for this experiment involving animal care were approved by the University of Minnesota Institutional Animal Care and Use Committee. Steers in this experiment were housed at the North Central Research and Outreach Center located in Grand Rapids, MN for a backgrounding phase divided into an individual feeding or grazing period and a common group-fed period. Steers were then transferred to the University of Minnesota's Beef Research and Education Complex located at UMore Park (Rosemount Research and Outreach Center) in Rosemount, MN for finishing on a common group-fed diet.

Cattle and Diets

Following weaning, 66 Angus steer calves (initial BW 198 kg ± 10 kg) were utilized in a 49-d individual backgrounding period or 29-d grazing period, followed by a common group-fed backgrounding period in an experiment arranged in a completely randomized design (69 d for cattle fed in a drylot and 81 d for cattle grazing). Fifty of the calves were adapted for 3 weeks to the Calan Broadbent feeding system (American Calan, Inc., Northwood, NH) and the remaining 16 steer calves were placed on grass pasture for these 3wk.

During a backgrounding phase where calves were fed individually, corn stover (untreated) was fed at 30% of diet DM (1) control diet (CON), (2) alkali-treated with 6% (DM basis) calcium hydroxide (TCS), or (3) treated with water (TWS) to bring moisture content to same concentration as TCS for 49 d; a fourth group of steer calves were permitted to graze (4) turnips seeded as a cover crop (CC) for 29 d. Nutrient concentrations of corn stover and other dietary ingredients are provided (Table 1). Remaining ingredients of backgrounding diets (Table 2) were (DM basis) 15% alfalfa haylage, 25% dried distiller's grains with solubles, 25% dry rolled corn, and 5% vitamin/mineral supplement. Steers were fed individually through a Calan Broadbent feeding system (American Calan, Inc., Northwood, NH); total mixed rations were mixed once per week with a horizontal mixer wagon (Model Kuhn 3136, Broadhead, WI) and stored indoors. A preservative (MYCO CURB, Kemin, Des Moines, IA) was added to total mixed rations to maintain diet and nutrient integrity; temperature during storage was less than 5 °C. Steers were fed dietary treatments once daily at 0600 h. Feed offered was adjusted according to the amount of feed offered and refused from the previous 2 d. Orts were weighed and sampled; subsequently composite samples of feed and orts were analyzed for DM to determine daily DMI. Ingredient and mixed diet samples were collected weekly. All feed refusal samples and dietary feedstuff samples were stored at -18˚ C until laboratory analysis.

Steers on the CC treatment had ad libitum access to graze on purple-top turnips (Brassica; Mousel, 2012) and annual ryegrass (Lolium multiflorum Lam.; Creamer et al., 1997). Cattle had access to a rotational grazing system wherein calves were rotated every 3 d. Every time calves were rotated to a new paddock, 10 samples from each paddock were collected and stored at -18˚ C until laboratory analysis. Samples were collected from each paddock by randomly throwing a 1-m^2 metal quadrant and clipping all vegetation within this area to ground level. Each sampling spot was at least 3 m from the previous sampling spot. Due to the heavy snowfall, steers on the CC treatment were removed from this treatment after 29 d. This group of cattle were moved to a pen (15 x 12 m) with a fence-line bunk (76 cm/hd) and were fed a common diet similar in composition to those of the other 3 dietary treatments (Table 2) for 85 d.

$Ca(OH)_2$ Treatment

Corn stover was processed through a bale processor (Model 2650 Balebuster, Haybuster, Jamestown, ND) and then chopped to 2.54 to 7.62 cm length through a chopper (Model 790 Chopper, John Deere, Moline, IL). Corn stover was then added to a TMR mixer (Model Kuhn 3136, Broadhead, WI), wetted to 50% moisture then $Ca(OH)_2$ (StoverCal, Mississippi Lime Company, St. Louis, MO) was added at 6% (DM basis). This same process was used to treat corn stover with water, but without the addition of $Ca(OH)_2$. Lastly, untreated corn stover was processed in the same manner without the addition of water or $Ca(OH)_2$ treatment. Corn stover treated or not was bagged and sealed in 2.44-m by 60.96-m Ag-Bag (Up North Plastics, INC., Cottage Grove, MN), and permitted to react for 32 d prior to feeding. Storage in silo bags was done to reach anaerobic conditions before and during the trial due to the high moisture content of the treated forages. Although unnecessary to maintain anaerobic conditions, untreated corn stover was also stored in this manner to standardize storage procedure across treatments.

Growth Performance

Steers were weighed on d 0, 29 (end of grazing period), 49 (end of individual backgrounding period) and at the end of the common backgrounding phase (63 d for grazing or 85 d for backgrounding calves). On weight days, BW was recorded after a 16-

h period during which steers had no access to feed or water. Steers were implanted with Revalor-G (Merck Animal Health, Madison, NJ) on d 1. Steers were then housed and fed a common diet for an additional 64 d (individually backgrounded) or 85 d (grazing group) before they were shipped to the University of Minnesota's Beef Research and Education Complex located at Rosemount Research and Outreach Center in Rosemount, MN for the finishing phase. Water and feed was removed the day before shipping so that arrival weight at the feedlot would coincide with a 16-h feed and water withdrawal period.

Finishing Phase and Carcass Data Collection

Upon arrival at the feedlot, initial BW was recorded and steers were vaccinated with an intranasal vaccine (Inforce-3, Zoetis, Florham Park, NJ), and rectal temperatures were recorded. Cattle with temperatures above 39.7˚C were treated with an antibiotic (Resflor Gold, Merck Animal Health, Madison, NJ). Interim BW was taken every 28 d before feeding. Steers were implanted on d 85 with Revalor S (Merck Animal Health, Madison, NJ), and a final BW was recorded on d 176 before being shipped to a commercial abattoir in Omaha, NE (Greater Omaha Packing Company Inc, Omaha, NE). Steers were harvested the following morning and slaughter order and hot carcass weight (HCW) were recorded. Following a 48-h chill at 4˚ C, camera measurements recorded LM area (LMA), and 12^{th} rib backfat. Marbling score, USDA Quality grade and USDA Yield Grade were assigned and provided by USDA personnel at the plant. Individual dressing percentage (DP) was calculated by dividing hot carcass weight by the un-shrunk weight recorded at the feedlot before trucking adjusted by the observed trucking shrink

(3.26%). A final adjusted BW was calculated from hot carcass weight and the common dressing percentage obtained from net load weight and carcass weight at the plant.

Sample Analysis

All samples were dried in a drying oven (Blue M Electric, Thermal Product Solutions, New Columbia, PA) at 55˚ C for 48 h to determine DM and then ground to pass through a 2-mm sieve using a Thomas Model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ). Feed refusals were determined by compositing dried refusal samples based on their individual contribution to total feed refused for each weight period (n = 2). Feed and refusal samples were analyzed for neutral detergent fiber (NDF; Van Soest et al., 1991), acid detergent fiber (ADF; Method 973.18, AOAC, 2000), crude protein (CP; Method 992.15, AOAC, 1995) and ether extract (EE; Method 920.39, AOAC, 2000). Neutral detergent fiber analysis was conducted using the Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, MY), where samples were extracted for 60 min at 100° C in NDF solution with heat sable α-amylase. Following NDF analysis, samples were dried at 100° C (Thelco 130 DM, Precision Scientific, Chicago, IL) then weighed; NDF percentage was calculated. Prior to the NDF analysis any sample that contained EE concentrations greater than 5% (corn and DDGS) were pre-extracted following biphasic extraction procedures (Bremer et al., 2010). Following the NDF analysis ADF was then analyzed utilizing the same procedure as NDF. However, with the ADF procedure ADF solution was utilized and samples were extracted for 60 min at 100° C followed by drying overnight at 100° C, weighing and then calculating ADF percentage. Ether extract analysis was completed by using an Ankom^{XT10} Extraction system (Ankom Technology, Macedon, NY) for 60 min at 90˚ C with petroleum ether.

In Situ DM and NDF disappearance

An in situ trial was completed at the University of Illinois, Urbana-Champaign, Illinois to determine in situ DM disappearance of corn stover samples (TCS, TWS, and CON). Two ruminally fistulated steers were used to determine in situ DM and NDF disappearance. Six hundred fifty g of sample (as-is) were artificially masticated (via hammer and scissors) and weighed into in situ bags (Ankom Technology, 10 x 20 cm). Samples were incubated in the rumen for 12, 24, 36, and 48 h. At each time point four replicate samples were collected from each of the two steers and bags were dried at 55˚ C for 3 d. An additional 4 bags were used as blanks to determine the "washout" (0 h) of each stover sample from in situ bags. Following drying, samples were weighed to determine in situ disappearance using the following equation (DM basis; Schroeder et al., 2014):

$$(1 - (\frac{\text{weight of stover before incubation}}{\text{weight of stover after incubation}}) \text{ x } 100)) – (1 - (\frac{\text{weight of stover before washout}}{\text{weight of stover after washout}}) \text{ x } 100)$$

NDF disappearance was determined using the weight of corn stover NDF in the same equation.

Statistical Analysis

Data on BW, ADG, DMI and kg gain achieved per kg feed DM from the individual backgrounding phase were analyzed using Proc Mixed procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). Individual steer (CON and TWS treatments contained 17 hd per treatment and the TCS and CC treatments contained 16 hd) was the experimental unit and initial body weight was used as a covariate. During the common backgrounding and finishing phase, only individual BW, ADG and carcass performance data were analyzed statistically. Preplanned orthogonal contrasts were conducted on performance and carcass data to determine effects of treating corn stover (TCS and TWS versus CON) stover treatment (TCS versus TWS), or the effects of backgrounding steers on a forage-based diet compared to grazing a cover crop on pasture (TCS, TWS and CON versus CC). Categorical data analysis (Proc Glimmix; SAS Institute Inc., Cary, NC) was conducted on USDA Quality grade data to determine the effects of treatment on Select versus Choice versus Prime, Select versus Choice and Prime, and Low Choice versus Premium Choice. For the in situ data replicate samples of corn stover was the experimental unit used and steer was considered a random effect. Dependent variables were DMD and NDFD and independent variables were ingredient, hour, and its interaction. For all analysis, effects were considered significant when a P value of less than 0.05 was obtained and was considered a trend when P values were between 0.05 and 0.10.

RESULTS AND DISCUSSION

In Situ

There were no effects of treatment on DMD ($P = 0.13$) and NDFD ($P = 0.26$) over time statistically, however numerically there were differences. Numerically, in situ DMD and NDFD of TCS was greater (43.49% and 54.82%) than that of CON (31.02% and 39.50%) or TWS (18.99% and 22.77%), respectively, at 48 h. Gandhi and Holtzapple (1998) reported faster rates of digestibility when treating wheat straw with calcium hydroxide. Results from the current in situ study did not support live performance differences as shown in Table 2.

Interim Growth Performance on Corn Stover Treatments

Treatment effects for interim and cumulative growth performance during 49 d on individual backgrounding (corn stover treatments) or grazing and common backgrounding (CC) are listed in Table 4. Cattle fed TWS during d 0 to 29 consumed more ($P < 0.0001$) DM and, at d 29, had heavier BW ($P = 0.01$) than those fed TCS, CON, or CC. Cattle fed TWS had faster ADG ($P < 0.0001$) than those fed TCS or CC; however, cattle fed CON had similar ADG ($P = 0.75$) as cattle fed TWS. Cattle grazing CC had lighter BW ($P < 0.0001$) at d 29 and 49. Feed conversion was not affected ($P = 0.31$) by feeding either TCS, TWS, or CON. From d 29 to 49, cattle fed TWS and TCS had higher DMI ($P = 0.0003$) than cattle fed CON; however, there was a tendency for cattle fed TCS to have lower DMI ($P = 0.08$) than cattle fed TWS.

During the first 49 d, cattle grazing CC and subsequently backgrounded in a pen had significantly slower ADG ($P < 0.0001$) than those fed TCS, TWS, or CON. Cattle fed TWS had significantly higher DMI from d 0 to 49 ($P = 0.0004$) than those fed TCS. Gross feed efficiency (ratio of live weight gain to DMI) was not significantly affected ($P = 0.33$) by treatment.

Soaking corn stover in water led to greater DMI; this observation is in agreement with that made by Ndlovu et al. (1989) using water-treated corn stover. Chaturvedi et al. (1973) found similar results after soaking wheat straw in water. In that experiment, cattle fed water-treated wheat straw had greater DMI and heavier BW. Feed efficiency was not affected by feeding treated corn stover (alkali or water) in this study; similar results were found by Russell et al. (2011) when feeding Ca-O treated stover silage to growing cattle.

Common Backgrounding Phase

Treatment effects for the common backgrounding phase are listed in Table 5. At d 29, cattle fed stover regardless of treatment had heavier BW (*P* = 0.0018) than cattle grazing a cover crop. However, cattle that grazed CC had significantly faster ADG (*P* = 0.0006) during the second 28 d on the common backgrounding phase than cattle previously fed corn stover regardless of treatment. From d 0 to 29, cattle that were fed TCS had significantly faster ADG (*P* = 0.0019) than those fed TWS. At the end of the common backgrounding phase, cattle previously on a corn stover treatment were heavier but those previously grazing CC had significantly faster rate of gain (*P* = 0.0094). This observation was similar to results from other research where cattle fed high forage diets exhibited greater ADG (Winterholler et al. 2008). This response was likely caused by compensatory gain.

Finishing Phase

Growth performance of steers over a 176-d finishing phase is listed in Table 6. Feeding cattle corn stover regardless of treatment or grazing a cover crop for a short grazing season before backgrounding and finishing had no impact on final BW (*P* = 0.73) or adjusted final BW (*P* = 0.49). Cattle fed TCS during backgrounding had significantly faster adjusted final ADG (*P* = 0.03) than cattle fed TWS. Similarly, there was a tendency (*P*= 0.08) for cattle fed a TCS to have a higher cumulative backgrounding and final adjusted ADG than those fed TWS. Cattle fed TCS likely compensated for a slower start during backgrounding. Cattle that were fed lower quality forage in a backgrounding phase subsequently permitted them to increase feed intake and have higher ADG (Greenwood et al. 2005) when finished on a higher energy diet in the finishing phase.

Carcass Characteristics

Carcass characteristics are listed in Table 7. Hot carcass weight, DP, marbling score and USDA Yield Grade and Quality Grade were all unaffected by dietary treatments. Cattle fed CON had a larger LM area ($P = 0.03$) than those fed either TCS or TWS. Cattle fed TWS tended to have smaller ($P = 0.06$) 12th rib fat depth than cattle fed TCS. Previous results from research by Shreck et al. (2012), Shreck et al. (2015) and Russell et al. (2011) supported lack of effect of corn stover treatment on marbling. Trend for greater fat depth as observed in this study was reported by Shreck et al. (2012), Shreck et al. (2015) and Russell et al. (2011).

Conclusion

Treating corn stover with calcium hydroxide numerically effected DMD or NDF; indeed, cattle fed corn stover treated with water consumed more feed and had greater gains, albeit at lower incremental feed conversion, during treatment period. Because of no impact on subsequent gains or carcass quality, we proved that an alternative to backgrounding cattle on low quality forages may be simply grazing a cover crop.

Table. 1 Nutrient composition of feedstuffs.

Nutrient, (DM basis)	DRC[1]	DDGS[2]	Haylage	CON[3]	TCS[4]	TWS[5]	Supplement[6,7]
DM, %	83.7	84.5	28.7	80.3	45.5	33.7	91.5
CP, %	8.0	25.5	15.8	4.7	5.0	4.1	18.0
NDF, %	15.4	44.2	47.7	78.7	60.3	80.9	25.0
ADF, %	2.4	9.5	30.5	48.5	41.8	50.3	6.8
Ether extract, %	3.8	7.3	-	-	-	-	-

[1]DRC = Dry rolled corn.

[2]DDGS = Dried distillers grains with solubles.

[3]CON = Control.

[4]TCS = Treated corn stover.

[5]TWS = Treated water stover.

[6]Supplement formulated to provide 234 mg monensin/hd/d (Rumensin, Elanco Animal Health, Greenfield, IN).

[7]MYCO CURB (Kemin, Des Moines, IA) added to supplement to reduce mold growth.

Table 2. Dietary inclusion and concentration (DM, after correcting for composition of feed offered and refused) of each individual dietary treatment.

	Treatment			
Item	CC[1]	CON[2]	TCS[3]	TWS[4]
Ingredient				
DRC[5]	25.0	23.9	24.9	25.7
DDGS[6]	25.0	23.7	24.6	25.3
Haylage	44.9	16.1	17.4	17.6
CON	-	30.9	-	-
TCS	-	-	27.5	-
TWS	-	-	-	25.7
Supplement[7,8]	5.1	5.4	5.6	5.7
Dietary nutrient concentration (offered)				
DM, %	43.8	63.8	49.8	48.8
CP, %	18.5	11.7	13.4	13.4
NDF, %	32.8	47.4	41.0	45.7
ADF, %	-	22.4	20.1	21.7
Dietary nutrient concentration (consumed)				
DM, %	-	64.0	49.7	48.9
CP, %	-	13.1	13.4	13.4
NDF, %	-	40.4	40.9	45.6
ADF, %	-	22.1	20.0	21.6

[1]CC = Cover Crop (fed after ending grazing period).
[2]CON = Control.
[3]TCS = Treated corn stover.
[4]TWS = Treated water stover.
[5]DRC = Dry rolled corn.
[6]DDGS = Dried distillers grain with solubles.
[7]Supplement formulated to provide 234 mg monensin/hd/d (Rumensin, Elanco Animal Health, Greenfield, IN).
[8]MYCO CURB (Kemin, Des Moines, IA) added to supplement to reduce mold growth.

Table 3. Effect of treatment on in situ DM and NDF disappearance.

		Treatment				P-Value		
Item	Hour	CON[1]	TCS[2]	TWS[3]	SEM	Ingredient	Hour	Ingredient x Hour
DMD		96.80	133.33	53.50	4.59	<.0001	0.01	0.13
	12	12.48	19.10	2.92				
	24	22.99	30.53	10.74				
	36	30.31	40.21	20.85				
	48	31.02	43.49	18.99				
NDFD[4]		122.23	157.17	52.81	5.49	<.0001	0.003	0.26
	12	13.87	20.13	-				
	24	25.29	34.60	6.30				
	36	33.57	47.60	18.04				
	48	39.50	54.82	22.17				

[1]CON = Control.
[2]TCS = Treated corn stover.
[3]TWS = Treated water stover.
[4]There is no value to report at 12 h for NDFD due to bags opening and sample lost.
(*P* < 0.05 considered significant *P* > 0.05 and ≤ 0.10 considered a trend).

Table 4. Interim and cumulative animal growth performance by steer calves individually fed a corn stover-based diet or turned out to CC pasture for the first 29 d.

Item	Treatment				SEM	Contrast[5]		
	CC[1]	CON[2]	TCS[3]	TWS[4]		1	2	3
n	16	17	16	17				
Initial BW, kg	200	196	202	195	9.54	0.84	0.65	0.84
d 0 to 29								
BW, kg	208	243	238	246	1.97	0.82	0.01	<0.0001
DMI, kg/d	-	5.29	4.87	6.04	0.17	<0.0001	<0.0001	-
ADG, kg	0.34	1.49	1.33	1.59	0.07	0.75	0.01	<0.0001
Gain:Feed	-	0.29	0.28	0.27	0.01	0.31	0.45	-
d 29 to 49								
BW, kg	245	263	265	272	2.73	0.09	0.12	<0.0001
DMI, kg/d	-	5.49	5.86	6.52	0.26	0.03	0.08	-
ADG, kg	1.95	1.06	1.43	1.35	0.07	0.0003	0.47	<0.0001
Gain:Feed	-	0.18	0.23	0.21	0.01	0.03	0.27	-
d 0 to 49								
BW, kg	245	263	265	272	2.73	0.09	0.12	<0.0001
DMI, kg/d	-	5.37	5.27	6.23	0.18	0.08	0.0004	-
ADG, kg	0.96	1.32	1.37	1.50	0.06	0.09	0.12	<0.0001
Gain:Feed	-	0.24	0.26	0.24	0.01	0.33	0.74	-

[1]CC = Cover crop.
[2]CON = Control.
[3]TCS = Treated corn stover.
[4]TWS = Treated water stover.
[5]Preplanned orthogonal contrasts: 1 = Untreated vs. treated corn stover (TCS and TWS vs. CON). 2 = Stover treatment (TCS vs. TWS). 3 = Backgrounding vs. pasture (CC vs. TCS, TWS, and CON). (P < 0.05 considered significant P > 0.05 and $\leq$ 0.10 considered a trend).

Table 5. Growth performance of steer calves fed in pens on a common backgrounding phase (CC d 0 to 85; CON, TCS, TWS d 0 to 64) before being shipped and housed at the University of Minnesota's Beef Research and Education Complex for the finishing phase.

	Treatment					Contrast[5]		
Item	CC[1]	CON[2]	TCS[3]	TWS[4]	SEM	1	2	3
n	16	17	16	17				
Weights, kg								
Initial	200	196	201	195	9.54	0.84	0.65	0.84
End of individual feeding	245	263	265	272	2.73	0.09	0.12	<0.0001
Common Phase								
d 0 to 29[2,3,4] or 49[1]	308	318	324	322	3.61	0.20	0.72	0.0018
d 29 to 64[2,3,4] or 85[1]	337	348	348	356	4.09	0.43	0.15	0.01
ADG, kg								
d 0 to 29[2,3,4] or 49[1]	2.22	1.96	2.10	1.81	0.06	0.97	0.0019	0.0006
d 29 to 64[2,3,4] or 85[1]	0.83	0.85	0.66	0.95	0.05	0.40	0.0002	0.90
Cumulative								
d 0 to 64[2,3,4] or 85[1]								
BW, kg	337	348	348	356	4.09	0.43	0.15	0.01
ADG, kg	1.44	1.34	1.29	1.32	0.04	0.51	0.53	0.0094

[1]CC = Cover crop.
[2]CON = Control.
[3]TCS = Treated corn stover.
[4]TWS = Treated water stover.
[5]Preplanned orthogonal contrasts: 1 = Untreated vs. treated corn stover (TCS and TWS vs. CON). 2 = Stover treatment (TCS vs. TWS). 3 = Backgrounding vs. pasture (CC vs. TCS, TWS, and CON). ($P < 0.05$ considered significant $P > 0.05$ and ≤ 0.10 considered a trend).

Table 6. Growth performance of steer calves fed a common DRC-base finishing diet at the University of Minnesota's Beef Research and Education Complex for the finishing phase.

Item	Treatment				SEM	Contrast[5]		
	CC[1]	CON[2]	TCS[3]	TWS[4]		1	2	3
n	16	17	16	17				
Weights, kg								
Initial	200	196	201	195	9.54	0.84	0.65	0.84
End of stover feeding	245	263	265	272	2.73	0.09	0.12	<0.0001
End of backgrounding	337	348	348	356	4.09	0.43	0.15	0.01
Finishing phase								
Final	629	639	634	625	9.96	0.43	0.51	0.73
Adjusted final [6]	625	641	640	622	10.81	0.42	0.24	0.49
ADG, kg								
Finishing phase								
Final	1.66	1.65	1.63	1.53	0.05	0.17	0.12	0.30
Adjusted final[6]	1.64	1.66	1.66	1.51	0.05	0.18	0.03	0.64
Cumulative								
Backgrounding and final	1.60	1.57	1.54	1.47	0.04	0.15	0.22	0.10
Backgrounding and final Adjusted	1.58	1.58	1.56	1.46	0.04	0.16	0.08	0.28
Overall	1.49	1.53	1.51	1.48	0.03	0.43	0.54	0.77
Adjusted overall	1.48	1.53	1.53	1.46	0.04	0.41	0.23	0.47

[1]CC = Cover crop.
[2]CON = Control.
[3]TCS = Treated corn stover.
[4]TWS = Treated water stover.
[5]Preplanned orthogonal contrasts: 1 = Untreated vs. treated corn stover (TCS and TWS vs. CON). 2 = Stover treatment (TCS vs. TWS). 3 = Backgrounding vs. pasture (CC vs. TCS, TWS, and CON). ($P < 0.05$ considered significant $P > 0.05$ and ≤ 0.10 considered a trend).
[6]Adjusted final = Carcass adjusted final BW was calculated from HCW using a common dressing percentage of 64.01%.

Table 7. Carcass characteristics, Yield Grades and Quality Grades for finishing steers fed forage based diets during the backgrounding phase and a DRC-based diet for the growing and finishing phase.

	Treatment					Contrast[5]		
Item	CC[1]	CON[2]	TCS[3]	TWS[4]	SEM	1	2	3
Carcass Characteristics								
HCW, kg	400	411	410	398	6.93	0.42	0.23	0.49
Dressing percentage, %	63.6	64.1	64.5	63.6	0.39	0.97	0.10	0.36
LM area, cm^2	79.6	84.2	80.1	79.0	1.68	0.03	0.63	0.45
12^{th} rib fat depth, cm	1.60	1.54	1.76	1.51	0.09	0.40	0.06	0.94
Marbling score[6]	634	624	653	641	24.75	0.46	0.74	0.86
USDA Yield grade[7]	3.11	3.08	3.22	3.14	0.16	0.58	0.72	0.84
						Contrast[10]		
USDA Quality grade[8]						1	2	3
Prime	1	2	0	1	-	0.97	0.98	0.98
Premium choice[9]	8	9	10	8	-	0.98	1.0	0.98
Low Choice	5	3	6	8	-	0.27	0.48	0.92
Select	2	3	0	0	-	-	-	-

[1]CC = Cover crop.
[2]CON = Control.
[3]TCS = Treated corn stover.
[4]TWS = Treated water stover.
[5]Preplanned orthogonal contrasts: 1 = Untreated vs. treated corn stover (TCS and TWS vs. CON). 2 = Stover treatment (TCS vs. TWS). 3 = Backgrounding vs. pasture (CC vs. TCS, TWS, and CON). ($P < 0.05$ considered significant $P > 0.05$ and ≤ 0.10 considered a trend).
[6]Marbling score scale: 400 = Se 500 = Ch^- 600 = Ch° 700 = Ch^+ 800 = Pr^-
[7]USDA Yield Grade 1 to 5 scale where 1 = high yielding carcasses and 5 = low yielding carcasses
[8]USDA Quality Grade scale: 1 = Se 2 = Ch^- 3 = Ch° 4 = Ch^+ 5 = Pr^-
[9]Premium Choice = average (Ch°) and high choice ($Ch^{+)}$
[10]Preplanned orthogonal contrasts: 1 = Untreated vs. treated corn stover (select vs. choice vs. prime), 2 =Stover treatment (select vs. choice and prime, 3 = Backgrounding vs. pasture (low choice vs. premium choice)

Chapter IV

INFLUENCE OF SUPPLEMENT FORM ON DIET INTEGRITY

K. L. Nenn and A. DiCostanzo

University of Minnesota, Department of Animal Science, St. Paul, 55108

SUMMARY

A 21-d study was designed to determine effect of supplement form (dry or liquid) on diet integrity and consistency. Cattle were already adapted to a high-grain diet comprised of (loading order as-is; liquid supplemented diet LS): haylage (13.6%), dry rolled corn (33.2%), barley grain screenings (10.2%), modified distillers grains (40.8%), and liquid supplement (2.3%) or (loading order as-is; dry supplemented diet DS) haylage (13.7%), dry rolled corn (32.8%), barley grain screenings (10.2%), modified distillers grains (41.0%) and dry supplement (2.3%). Diets were mixed in a Patz 420 vertical mixer; after the last ingredient was added, diets were permitted to mix for 5 min before delivery. Diets were delivered once daily to 5 or 4 pens assigned to LS and DS, respectively, following the same pen delivery sequence throughout the study. Reference concentrations of DM, NDF, CP, Ca, Zn and Cu were derived from concentrations of these nutrients in samples collected immediately before preparing a batch (liquid or dry) composited using ingredient amounts loaded on each of 9 sampling dates (Monday, Wednesday and Friday of each of 3 wk). Reference nutrient concentrations were considered target concentrations for each bunk sample. Reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples (n = 9 sites across bunks) collected from permanently identified bunk locations 3.7 m apart; these differences represented deviations from reference values and were subjected to statistical analyses. Data were analyzed as a split plot design with repeated measures in time. Findings from this study demonstrated that supplement form affected concentrations of DM, CP, Ca and Cu delivered to the bunk. Concentrations of DM and CP were closest to reference values when LS was used but those of Ca and Cu were

closest to reference values when DS was used. Results from this study demonstrated that concentrations of Zn moved further away from the reference value as the mixer approached the end of delivery sites. Through this short-term study, we have demonstrated that supplement form and, for micro-minerals such as Zn, delivery order may impact nutrient concentrations in bunk samples.

Keywords: supplement type, diet integrity, nutrient availability

INTRODUCTION

Dairy and beef producers use total mixed rations (TMR) to deliver measured and balanced concentrations of nutrients to achieve their production goals (Spain et al., 1993). Total mixed rations have been used for decades but tools and efforts aimed at improving TMR mix integrity and consistency continue to improve (Buckmaster, 2005). The main goal for using a TMR mixer is to minimize within-batch and between-batch variation in moisture, particle size, and concentrations of energy, protein, minerals, and vitamins (Oelberg, 2009). Various factors affect TMR mix integrity and consistency including particle size, loading order and load, mixer type and condition, mixing time amongst others.

There is anecdotal evidence that supplement ingredient form (liquid or dry) may impact diet integrity. Yet, choice of supplement form is based on previous experience, storing site, loading and mixing equipment, and perception of cost of nutrient delivery (Pritchard et al. 2015). Liquid supplements are easy to store and offer long shelf-life. However, liquid supplementation can become a problem if liquid is not properly mixed in a diet. Oelberg (2009) found that under-mixing a liquid supplement in a TMR led to the first 10 to 15% of the delivery in the bunk being wetter than deliveries made in the middle or end of the bunk. Dry supplements may cause these same problems if they are not properly mixed; the supplement may bunch up in the ration when loaded at the wrong time relative to moist ingredients, particularly.

There is some evidence that indicates that choice of supplement form may impact performance (Pritchard et al., 2015); whether this observation resulted from consistent diet integrity is not clear, but no direct evidence is available demonstrating if supplement form may enhance dietary integrity. Therefore, we sought to understand how supplement form impacts diet integrity and consistency in a short-term study using a finishing diet.

MATERIALS AND METHODS

This experiment took place at the Beef Research and Education Complex located at UMore Park (Rosemount Research and Outreach Center) in Rosemount, MN.

Diets and Equipment

Total mixed rations (TMR) were mixed daily at 0800 h with a vertical mixer (Model V420, Patz Corporation, Pound, WI) power-driven by a tractor (Model 6155R, John Deere Inc., Moline, IL). A feedlot diet supplemented with either a liquid (LS) or dry supplement (DS) containing vitamins, minerals, and protein (Table 1) was fed for 21 d and delivered in bunks to 9 pens of growing cattle (5 were assigned to LS and 4 were assigned to DS). Cattle housed in pens 1, 2, 3 (7 m linear space serving 17 hd each), and 5 (18 m linear space serving 51 hd each) were fed DS diet, while cattle housed in pens 4 (7 m linear space serving 17 hd), 6 (18 m linear space serving 51 hd), 115, 114, and 113 (9 m linear space serving 10 hd) were fed LS diet (Figures 1 and 2). Cattle had been previously adapted to the diet with the liquid supplement. Thus, diets were formulated (as-is) and loaded in the following order: for the LS diet, 13.6% grass silage, 10.2% barley grain screenings, 33.2% dry rolled corn, 40.8% modified dried distillers grain, and 2.3% LS (QLF CoreMax 20 R600, Quality Liquid Feeds, Dodgeville, WI), and the DS diet, 13.7% grass silage, 10.2% barley grain screenings, 32.8% dry rolled corn, 41.0% modified dried distillers grain, and 2.3% DS (UofM 20 R600, AgPartners, Pine Island, MN).

Delivery

Batch totals were determined based on estimates of intake derived from visual appraisal of bunks (bunk scores: 0, bottom of bunk was empty and dry, to 4, delivered feed crown as not disturbed) assigned 30 min prior to mixing. Each diet was mixed for 5 min and delivered to bunks in the same order every day. Prior to loading, liquid supplement was mixed for 10 min in the tank to ensure that ingredients were in suspension. Before mixing each diet, ingredient samples were collected, from a site representative of the area from where ingredients were loaded, and immediately frozen for later analysis.

Sampling

Nutrient concentrations (DM, NDF, CP, Ca, Zn, and Cu) were measured on feed ingredient and bunk samples collected on Monday, Wednesday, and Friday of each week for a total of 3 consecutive weeks (n = 9). Feed ingredient samples were collected prior to loading each ingredient when preparing each diet during these days. Reference nutrient concentrations were then derived from composite concentrations of feed ingredient samples collected at the time of loading each ingredient when mixing each diet.

Bunk samples (4-kg; n = 9 sites across delivery length) were collected in tin trays (25 x 30 cm) at permanently identified locations 3.7 m apart starting at the beginning of the delivery immediately after delivery. The same tray was used at the same spot for every sampling. Immediately after collection, samples were frozen at -18˚ C for later analysis to determine concentrations of DM, NDF, CP, Ca, Zn, and Cu.

Sample Analysis

Prior to laboratory analysis, feed ingredients and bunk samples were dried in a drying oven (Blue M Electric, Thermal Product Solutions, New Columbia, PA) at 60° C for 48 h to determine dry matter (DM). All samples were then ground to pass through a 2-mm screen using a Thomas Model 4 Wiley Mill (Thomas Scientific, Swedesboro, NJ). Feed ingredient samples were analyzed for neutral detergent fiber (NDF; Van Soest et al., 1991), crude protein (CP; Method 992.15, AOAC, 1995) and mineral analysis of Ca, Zn, and Cu by ICP-emission spectroscopy (Method 985.01, AOAC, 1995). All samples analyzed for CP were prepared and shipped to an outside lab to be analyzed following the procedure of Ciriaco et al. (2015). All samples analyzed for Ca, Zn, and Cu concentrations were prepared and shipped to an outside lab (Dairyland Laboratories, Inc., Arcadia, WI) to be analyzed using the procedure of Fassel and Kniseley (1974). All other chemical analysis was completed in house.

Neutral detergent fiber analysis was conducted using the Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, MY), where samples were extracted for 60 min at 100° C in NDF solution with heat sable α-amylase. Following NDF analysis, samples were dried at 100° C (Thelco 130DM, Precision Scientific, Chicago, IL) then weighed and NDF percentage was calculated. Prior to the NDF analysis any sample that contained ether extract (EE) concentrations greater than 5% (corn, modified dried distillers grain, TMR samples) were pre-extracted following biphasic extraction procedures (Bremer et al., 2010). This was a necessary as fat in samples containing EE concentration of 5% (high fat) or greater not having fat pre-extracted were contaminated with fat during the NDF procedure. This will inflate EE concentration in these samples.

Statistical Analysis

Reference nutrient concentrations were considered target concentrations for each bunk sample. These reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples at each sampling site. These values represented measured deviations from reference values, measures of accuracy, and were subjected to statistical analyses. Nutrient concentration deviation data were analyzed using Proc Mixed procedures of SAS 9.4 (SAS Institute Inc., Cary, NC). A split-plot design with repeated measures in time (day of collection) and place (location of collection within a delivery) was used; the interaction of collection and order within pen was the error term for measuring main effects. Significant effects of time or place, within supplement form, reflected variations in precision while those, across supplement form, reflected variations in accuracy. The power spatial covariance structure SP (POW) was used as collections were not equally spaced. Means were separated using least square means by opting for PDIFF in SAS.

RESULTS AND DISCUSSION

Effect of supplement form on deviations from references nutrient concentrations is listed in Table 2. Deviations from reference values for NDF or Zn concentrations did not differ between supplement type; numerical deviations for NDF were within 1.6 percentage units while those for Zn were as much as 7.7 ppm different from reference values (Table 2).

Deviations from reference values for DM, CP, Ca and Cu were statistically ($P <$ 0.05) different across sample dates by supplement type**.** Deviations for DM and CP were smaller (within 1.1 percentage unit; $P < 0.001$) within samples collected from LS deliveries. Sprague (2001) found that dry supplements lead to dust and fines in the ration; this could have led to greater variation in DM observed using the DS. No other differences between supplement type on deviations from reference value were detected over time. Pritchard (1993) observed that formulating diets with liquid supplements led to greater uniformity of nutrient concentration. However, deviations for Ca and Cu were smaller (within 0.2 percentage units and 4.4 ppm; $P < 0.01$) within samples collected from DS deliveries. Thus, across collection dates and sites, using LS in the current formulation led to concentrations of macro nutrients, such as DM and CP, to be closer to reference values (more precise deliveries) yet using DS led to concentrations of Ca and a micro-nutrient, Cu, to be closer to reference values.

Over the course of the experiment, differences in concentrations of DM were observed for each supplement form. There was a significant ($P < 0.05$) difference between supplement type DM on most collection days (2, 5, 6, 7, 8, and 9; Fig. 3). Yet, these observations reflected no specific pattern by collection date demonstrating random, not responsive to supplement form, variability in accuracy and precision of DM delivery.

Regardless of supplement type, delivery order had the greatest effect on bunk sample concentrations of Zn, Cu, and Ca (Fig. 4). The first order of delivery for Zn was closest to the reference value; by 1/3 of the delivered load, Cu concentrations were farther apart from reference values, and continued to get further from to reference values by the end of delivery. Concentrations of Ca were closest to reference value at the first collection site, and were larger yet than reference at the second collection site, but did not differ across the remaining collection sites. Similar to Ca, concentrations of Cu were closest to the target value within the first 2 collection sites and remained at the same difference from reference value throughout the remainder of collection sites.

Concentrations of DM, NDF, and CP were not statistically ($P > 0.05$) affected by order of delivery (Fig. 5). Buckmaster (2005) found that mixing time and loading order may affect overall mix uniformity and nutrient concentrations.

Overall, it is apparent that order of delivery may impact concentrations of micro minerals more than it does concentrations of macro nutrients, including Ca. Given these observations, it may be clear that conditions of loading and mixing were such in the current experiment that within date, most nutrients measured, with the exception of Zn, were fairly consistently delivered regardless of supplement form.

Conclusion

Findings from this study demonstrated that supplement form affected concentrations of DM, CP, Ca and Cu delivered to the bunk. Concentrations of DM and CP were closest to reference values when LS was used but those of Ca and Cu were closest to reference values when DS was used. Results from this study demonstrated that concentrations of Zn moved further away from the reference value as the mixer approached the end of delivery sites. Through this short-term study, we have demonstrated that supplement form and, for micro-minerals such as Zn, delivery order may impact nutrient concentrations in bunk samples. These findings may serve as evidence that potentially greater differences may be found under commercial conditions as results of this study were derived using a single operator and same loading, mixing and delivery approach across days.

Table 1. Ingredient composition of diets (DM basis).

Nutrient	DS[1]	LS[2]	SEM
	----------------------% diet DM---------------------		
Haylage	8.3	8.3	-
Barley screenings	13.9	14.1	-
MDGS[3]	29.7	29.6	-
DRC[4]	44.7	45.7	-
Supplement[5]	3.4	2.4	-
DM	63.6	63.5	1.36
CP	15.8	15.7	0.21
NDF	31.3	31.5	0.44
	----------------------mg/kg diet DM---------------------		
Ca	0.8	0.8	0.04
Zn	107.0	103.0	11.8
Cu	15.0	14.0	0.8

[1]DS = Dry Supplement.

[2]LS = Liquid Supplement.

[3]MDGS = Modified dried distillers grain.

[4]DRC = Dry rolled corn.

[5]Supplement formulated to provide 238 mg monensin/hd/d (Rumensin, Elanco Animal Health, Greenfield, IN).

Table 2. Effect of supplement type on deviations from reference values[1].

Ingredient	DS[2]	LS[3]	SEM	P – Value
D_DM[4]	2.7	1.1	0.19	<0.0001
D_NDF[5]	1.6	1.4	0.26	0.7133
D_CP[6]	-1.1	-0.4	0.15	0.0008
D_Ca[7]	0.2	0.3	0.01	0.0008
D_Zn[8]	7.7	2.3	2.20	0.2617
D_Cu[9]	4.4	5.4	0.26	0.0068

[1]Reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples at each sampling site.
[2]DS = Dry Supplement.
[3]LS = Liquid Supplement.
[4]D_DM = Dry matter difference from reference value.
[5]D_NDF = NDF difference from reference value.
[6]D_CP = CP difference from reference value.
[7]D_Ca = Ca difference from reference value.
[8]D_Zn = Zn difference from reference value.
[9]D_Cu = Cu difference from reference value.

Figure 1. Bunk sampling locations and delivery routes (white: 4, 6, 115, 114, and 113; yellow: 1, 2, 3, and 5) at the Beef Research and Education Complex located at Rosemount Research and Outreach Center in Rosemount, MN (Google Inc., Mountain View, CA). Diet formulated with a dry supplement (DS) was delivered to bunks labeled 1, 2, 3, and 5 while diet formulated with liquid supplement (LS) was delivered to bunks 4 and 6 in the order depicted here.

Figure 2. Bunk sampling locations and delivery routes (white: 4, 6, 115, 114, and 113; yellow: 1, 2, 3, and 5) at the Beef Research and Education Complex located at Rosemount Research and Outreach Center in Rosemount, MN (Google Inc., Mountain View, CA). Diet formulated with liquid supplement (LS) was delivered to bunks 115, 114 and 113 (pen 113 is not shown here) in the order depicted here.

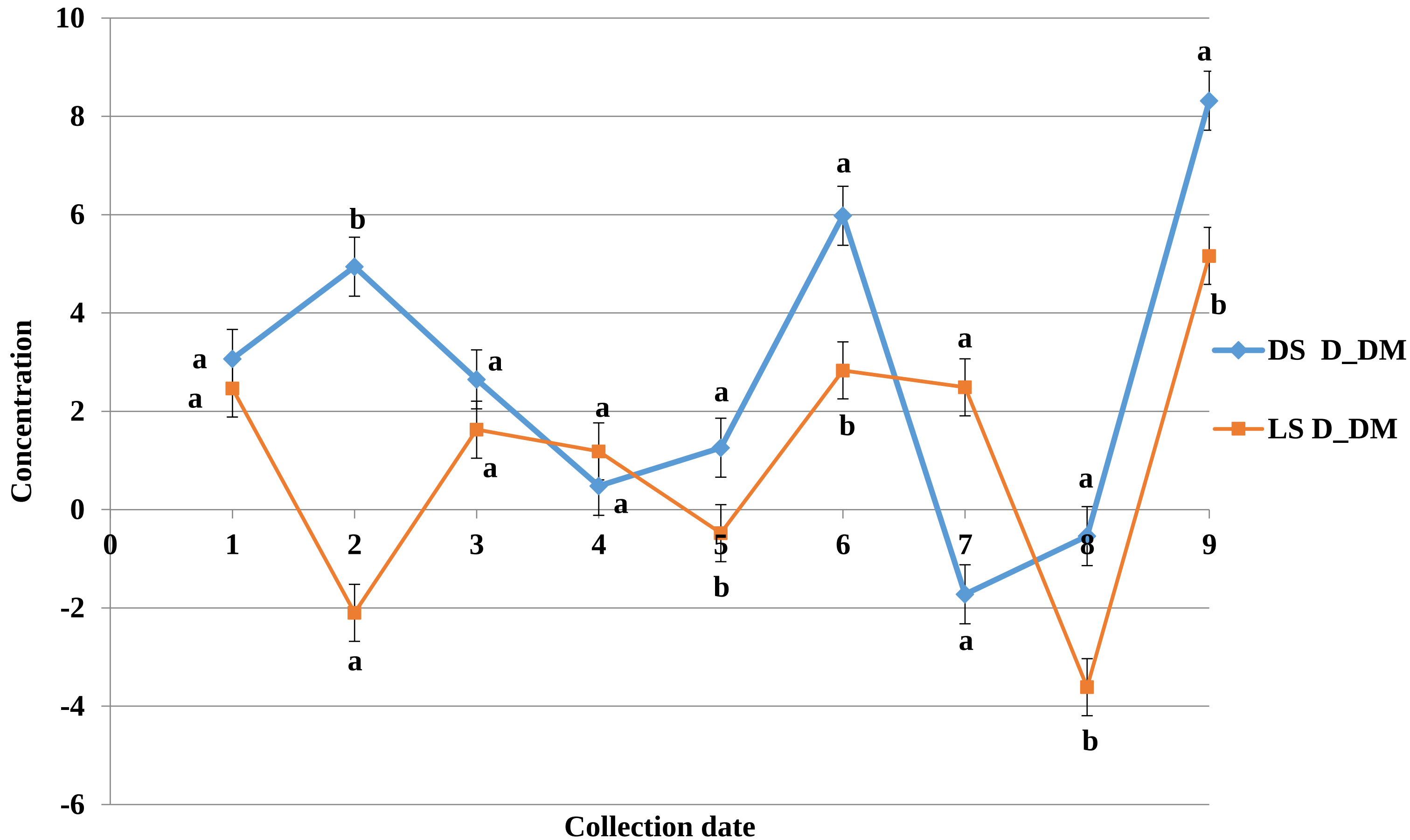

Figure 3. Effect of supplement type and sampling date on DM deviations from reference concentrations. Reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples at each sampling site. DS D_DM = dry supplement difference of reference value and LS D_DM = liquid supplement difference of reference value. [ab]Means with different superscript differ ($P < 0.05$).

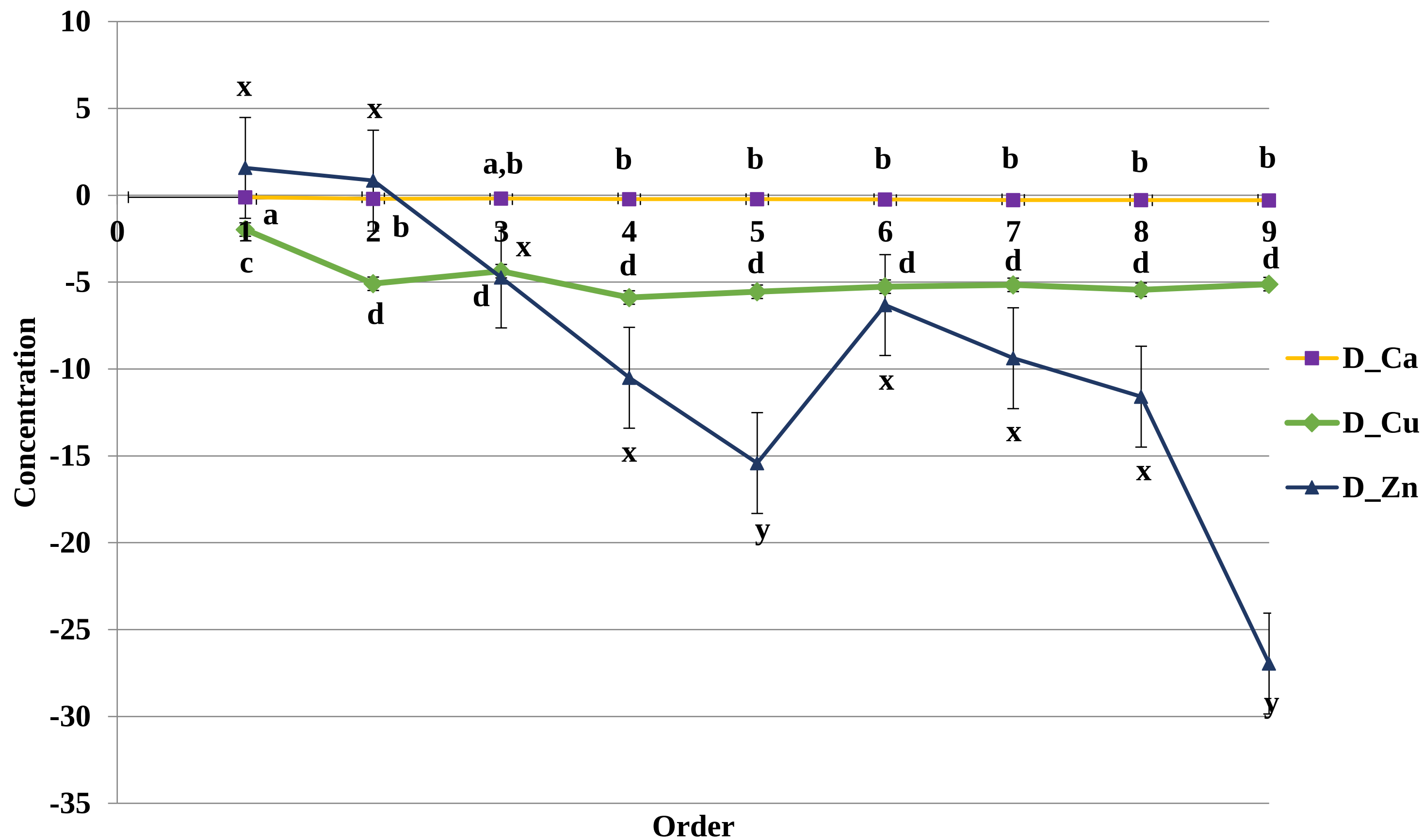

Figure 4. Effect of delivery order on mineral concentration deviations from references values. Reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples at each sampling site. D_Ca = calcium difference from reference value, D_Cu = copper difference from reference value, and D_Zn = zinc difference from reference value. [abcdxy]Means with different superscript differ ($P < 0.05$).

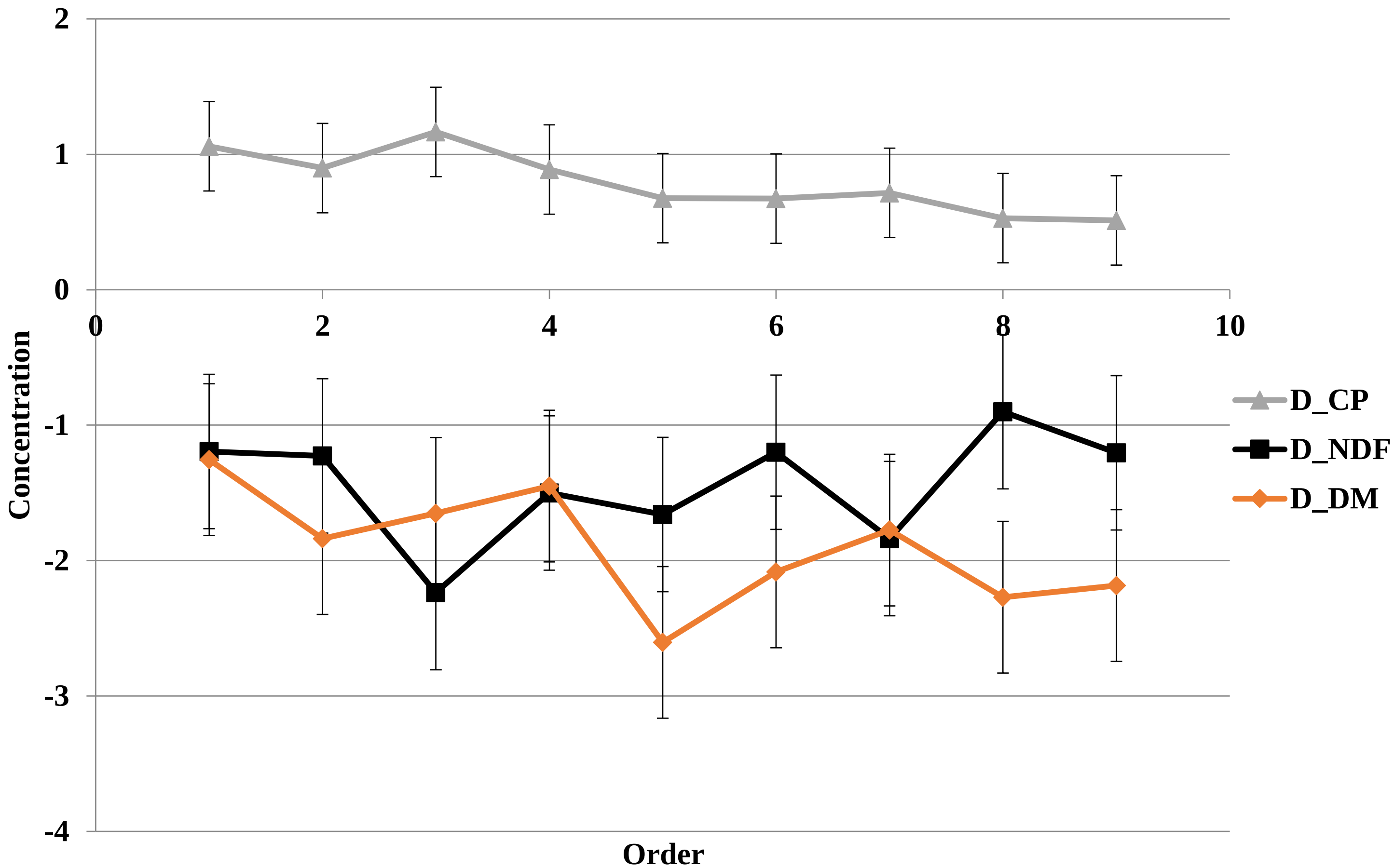

Figure 5. Effect of delivery order on deviations from references values. Reference concentrations were subtracted from respective concentration of each nutrient measured in bunk samples at each sampling site. D_CP = crude protein difference of reference value, D_NDF = neutral detergent fiber difference of reference value, and D_DM = dry matter difference of reference value. Reference concentrations did not differ (*P* > 0.05).

LITERATURE CITED

Aasen, A., V. S. Baron, G. W. Clayton, A. C. Dick, and D. H. McCartney. 2004. Swath grazing of potential spring cereals, field pea and mixtures with other species. Can. J. Plant. Sci. 84:1051-1058.

Anderson, D. C. and A. T. Ralson. 1973. Chemical treatment of ryegrass straw: In vitro dry matter digestibility and compositional changes. J. Anim. Sci. 37:148.

AOAC. 1995. Official Methods of Analysis. Assoc. Off. Anal. Chem. 16th editi.

AOAC. 2000. Official Methods of Analysis. Assoc. Off. Anal. Chem. 17th editi.

Ball, D., M. Collins, G. Lacefield, N. Martin, D. Mertens, K. Olson, D. Putnam, D. Undersander, M. W. 2001. Understanding forage quality. American Farm Bureau Federation Publication 1-01, Park Ridge, IL. 1–18.

Baxter, H. D., B. L. Bledsoe, M. J. Montgomery, and J. R. Owen. 1986. Comparison of alfalfa-orchardgrass hay stored in large round bales and conventional rectangular bales for lactating cows. J. Dairy Sci. 69:1854–1864.

Belyea, R. L., F. A. Martz, and S. Bell. 1985. Storage and feeding losses of large round bales. J. Dairy Sci. 68:3371–3375.

Bjorkman, A. 1957. Lignin and lignin-carbohydrate complexes. Indus. Eng. Chem. 49:1395-1398.

Blaser, R., R. C. Hammes, Jr., J. P. Fontenot, H. T. Bryant, C. E. Polan, D. D. Wolf, F. S. McClaugherty, R. G. Klein, and J. S. Moore. 1986.Forage–animal management systems. Virginia Polytechnic Institute, Bulletin 86-7.

Bourquin, L. D. and G. C. Fahey. 1994. Ruminal digestion and glycosyl linkage patterns of cell wall components from leaf and stem fractions of alfalfa, orchardgrass, and wheat straw. J. Anim. Sci. 72:1362-1374.

Bremer, V. R., C. D. Buckner, A. Brown, T. P. Carr, R. Diedrichsen, G. E. Erickson, and T. J. Klopfenstein. 2010. Lipid and NDF Analysis of Ethanol Byproduct Feedstuffs. Nebraska Beef Cattle Report. MP93:83-86.

Buckmaster, D. R. 2005. TMR delivery and variability on the farm. In: Dairy Cattle Nutrition Workshop; Pennsylvania State University.

Buckmaster, D. 2009. Optimizing Performance of TMR Mixers. In: Tri-State Dairy Nutrition Conference Proceedings. p.105–117.

Buskirk, D. D., A. J. Zanella, T. M. Harrigan, J. L. Van Lente, L. M. Gnagey, and M. J. Kaercher. 2003. Large round bale feeder design affects hay utilization and beef cow behavior. J. Anim. Sci. 81:109–115.

Chaturvedi, M. L., U. B. Singh, and S. K. Ranjham. 1973. Effect of feeding water-soaked and dry wheat straw on feed intake, digestibility of nutrients and VFA production in growing zebu and buffalo calves. Journal of Agrcultural Science, Cambridge 80: 393-397.

Ciriaco, F. M., D. D. Henry, V. R. G. Mercadante, T Schulmesiter, M. Ruiz-Moreno, G. C. Lamb, and N. DiLorenzo. 2015. Effects of different levels of supplementation of a 50:50 mixture of molasses: crude glycerol on performance, Bermuda grass hay intake, and nutrient digestibility of beef cattle. J. Anim. Sci. 93:2428-38.

Creamer, N. G., M. A. Bennet, and B. R. Stinner. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience. 32:866-870.

Coblentz, W. K., J. E. Turner, D. A. Scarbrough, K. E. Lesmeister, Z. B. Johnson, D. W. Kellogg, K. P. Coffey, L. J. McBeth, and J. S. Weyers. 2000. Storage characteristics and nutritive value changes in bermudagrass hay as affected by moisture content and density of rectangular bales. Crop Sci. 40:1375–1383.

Cooper, R., B. Dicke, D. J. Jordon, T. Scott, C. Macken, and G. E. Erickson. 2014. Impact of feeding alkaline-treated corn stover at elevated amounts in commercial feedlot cattle. Nebraska Beef Cattle Report.MP99:69-71.

Dahlke, G., and D. R. Strohbehn. 2009. Feed particle separation due to feed delivery and time in feed bunk and effects on cattle performance. Iowa State University Animal Industry Report: AS 655, ASL R2422.

Dicostanzo, A. and J. Jaderborg. 2015. Supplementation strategies to reduce waste in beef cattle systems. In: 26th Florida Ruminant Nutrition Symposium. 131–143.

Duckworth, M. J., A. Schroeder, D. B. Faulkner, D. Shike and T. L. Felix. 2013. Effects of feeding CaO treated modified wet distillers grains with solubles or corn stover to cattle on performance, carcass characteristics, and ruminal metabolism. MS thesis. Univ. of Illinois, Urbana.

Fassel, V. A, and R. N. Kniseley. 1974. Inductively coupled plasma. Optical emission spectroscopy. Ana. Chem. 43:1110A-1120a

Gandhi, J. P., and M. T. Holtzapple. 1998. Calcium hydroxide of millet straw to improve its rumen digestibility. Anim. Prod. Aust. 22:122-124.

Gigax, J. A., C. D. Buckner, L. A. Stalker, T. J. Klopfenstein, and S. J. van Donk. 2011. Effect of stocking rate on animal performance and diet quality while grazing cornstalks. Nebraska Beef Cattle Report. MP94:33-34.

Greenwood P.L., L. M. Cafe, H. Hearnshaw, and D.W. Hennessy. 2005. Consequences of nutrition and growth retardation early in life for growth and composition of cattle and eating quality of beef. Recent advances in Animal Nutrition in Australia 15: 183-195.

Harty. A. 2014. Importance of calcium and phosphorous in the ruminant diet. iGrow. Available from: http://igrow.org/livestock/beef/importance-of-calcium-and-phosphorus-in-the-ruminant-diet/. (Accessed 5 June 2016).

Heinrichs, A. J., D. R. Buckmaster, and B. P. Lammers. 1999. Processing, mixing, and particle size reduction of forages for dairy cattle. J. Anim. Sci. 77:180-186.

Hoffelt, J. 2011. Develop Hay Feeding Strategies to Avoid Winter Waste. Agri-View. Available from: http://www.agriview.com/news/livestock/develop-hay-feeding-strategies-to-avoid-winter-waste/article_f232ceb4-325b-11e1-b85b-0019bb2963f4.html. (Accessed 4 April 2016).

Holtzapple, M., and W. Kaar. 2000. Using lime pretreatment to facilitate the enzymatic hydrolysis of corn stover. Biom. Bioe. 18:189–199.

Jung, H. G. and M. S. Allen 1995. Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. J. Anim. Sci. 73:2774–2790.

Kallenbach, R. 2000. Reducing losses when feeding hay to beef cattle. Univ. Missouri Coop. Ext. Agric. Guide G-4750. Univ. Missour, Columbia.

Kinder, C. A. 2004. Growing and utilizing turnips as forages. Proceedings, Idaho Alfalfa and Forage Conference, 24-25.

Klopfenstein, T., and F. G. Owen. 1981. Value and potential use of crop residues and by-products in dairy rations. J. Dairy. Sci. 64:1250-1268.

Klopfenstein, T. J. 1978. Chemical treatment of crop residues. J. Anim. Sci. 46:841–848.

Koch, D.W. 2015. Brassicas for Fall Grazing. University of Wyoming Extension Department of Plant Science. B-1122.6.

Landblom, D. G., G. P. Lardy, R. Fast, C. J. Wachenheim, and T. A. Petry. (2007). Effect of hay feeding methods on cow performance, hay waste, and wintering cost. Prof. Anim. Sci. 23:246–252.

Lardy, G. and V. Anderson. 2009. Alternative feeds for ruminants. NDSU Extension Service. AS-11821:1-24.

Lechtenberg, V. L., W. H. Smith, S. D. Parsons, and D. C. Petritz. (1974). Storage and feeding of large hay packages for beef cows. J. Anim. Sci. 39:1011-1015.

Loerch, S. 1996. Limit-feeding corn as an alternative to hay for gestating beef cows. J. Anim. Sci. 74:1211-1216.

Loy, D. 2010. Feed management – bunker to bunk. Feedlot Forum Proceedings. 21-25.

Miller, A. J., D. B. Faulkner, R. K. Knipe, D. R. Strohbehn, D. F. Parrett, and L. L. Berger. 2001. Critical control points for profitability in the cow-calf enterprise. Prof. Anim. Sci. 17:295.

Miller, A. J., D. B. Faulkner, T. C. Cunningham, and J. M. Dahlquist. 2007. Restricting time of access to large round bales of hay affects hay waste and cow performance. Prof. Anim. Sci. 23:366-372.

Moore W. A. and W. J. Sexten. 2015. Effect of bale feeder and forage on hay waste, disappearance, and sorting. Prof. Anim. Sci. 31:248-254

Mousel, E. 2012. Incorporating cover crops into calf backgrounding programs. University of Minnesota Extension North Central Research and Outreach Center.

Ndlovu, L. R., Z. Manyame an M. Pleasant. 1989. Hydration as a means of improving utilization of maize corn stover fed to steers. Overcoming Constraints to the Efficient Utilization of Agricultural By-Products as Animal Feed. 343.

NRC. 2000. Nutrient requirements of beef cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589–596.

Oelberg, T. J., and W. Stone. 2014. Monitoring total mixed rations and feed delivery systems. Vet. Clin. Food. Anim. 30:721-744.

Oelberg, T. 2009. Tips for improving TMR consistency. Hoard's West. Available from: http://www.diamondv.com/wp-content/uploads/Reprint_Dairy_2009-12_Hoards_TMRConsistency.pdf. (Accessed 15 April 2016).

Oliveros, B. A., R. A. Britton, and T. J. Klopfenstein. 1993. Ammonia and/or calcium hydroxide treatment of maize stover: intake, digestibility and digestion kinetics. Anim. Feed Sci. and Technol. 44:59–72.

Pritchard, R. H., A. R. Taylor, and H. Blalock. 2015. Effectiveness of High inclusion feed for finishing steers. South Dakota State University.1–5.

Pritchard, R. H.. 1993. Role of supplement form for finishing yearling steers. South Dakota Beef Report. 13:48-53.

Rasby, R. 2015. Profit Tip: Forage Feeding Losses Can Add up. UNL Beef Profit Tips. Available from: http://beef.unl.edu/stories/200809260.shtml. (Accessed 8 April 2016).

Rasby, R. and J. Martin. 2015. Understanding Feed Analysis. UNL Beef Learning Modules. Available from: http://beef.unl.edu/learning/feedanalysis.shtml (Accessed 8 April 2016).

Russell, J. R., D. D. Loy, J. A. Anderson, and M. J. Cecava. 2011. Potential of chemically treated corn stover and modified distiller grains as a partial replacement for corn grain in feedlot diets. ISU Anim. Ind. Rep. AS 665:ASL R2586.

Rounds, W. and T. Klopfenstein. 1974. Chemicals for treating crop residues. J. Anim. Sci. 39:251. (Abstr.).

Schroeder, A. R., M. Iakiviak, and T. L. Felix. 2014. Effects of feeding dry or modified wet distillers grains with solubles with or without supplemental calcium oxide on ruminal metabolism and microbial enzymatic activity of beef cattle. J. Anim. Sci. 92:3997-4004.

Schuler, N., D. R. Strohbehn, D. D. Loy, C. J. Bern, and T. J. Brumm. 2011. Mixing Wet Distillers Grain in Beef Feed Rations. Iowa State University Animal Industry Report: AS 657, ASL R2590.

Shreck A. L., B. L. Nuttelman, W. A. Griffin, T. J. Klopfenstein, and M. J. Cecava. 2012. Chemical treatment of low-quality forage to replace corn in cattle finishing diets. Nebraska Beef Cattle Reports:690.

Shreck, A. L., B. L. Nuttelman, J. L. Harding, W. A. Griffin, G. E. Erickson, T. J. Klopfenstein, and M. J. Cecava. 2015. Digestibility and performance of steers fed low quality crop resides treated with calcium oxide to partially replace corn in distillers grains finishing diets. J. Anim. Sci. 93:661-671.

Solaiman, S. G., G. W. Horn, and F. N. Owens. 1979. Ammonium hydroxide treatment on wheat straw. J. Anim. Sci.49:802-808.

Spain, J., M. Bennett, D. Williams, and D. Osburn. 1993. Total mixed rations: Plan, uses, and economics by herd size. Univ. of Missouri. G3106.

Sprague, J. I. (2001). Dry vs. Liquid Supplements. Feedlot magazine. 9:4.

St. John, L., D. Tilley, and K. Jensen. 2012. Plant Guide for Meadow Brome (Bromus biebersteinii). USDA-Natural Resources Conservation Service, Aberdeen Plant Materials Center. Aberdeen, Idaho 83210.

Terashima, N., K. Fukushima, L. F. He, and K. Takabe. 1993. Comprehensive model of the lignified plant cell wall. In: H. G. Jung, D. R. Buxton, R. D. Hatfield, and J. Ralph (Ed.) Forage Cell Wall Structure and Digestibility. p 247. ASA-CSSA-SSSA, Madison, WI.

Torell, R., and J. Balliette. 2013. Beef Cattle Handbook: Pricing Protein and Energy Supplements. Iowa Beef Center. Available from: http://www.iowabeefcenter.org/Beef%20Cattle%20Handbook/Pricing_Protein_Energy_Supplements.pdf.

Undersander, D. J., A. R. Kaminski, E. A. Oelke, L. H. Smith, J. D. Doll, E. E. Schulte, and E. S. Oplinter. 1991. Turnip. Alter. Field Crops Manual.

USDA NRCS Plant Materials Program. 2017. Plant Profile. https://plants.usda.gov/core/profile?symbol=ELRE4. (Accessed 5 August 2017).

Van Soest. P. J., J. B. Robertson, and B. A. L. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583–3597.

Walker, R. S., D. LaMay, J. R. Davis, and C. A. Bandyk. 2013. Case study: method of feeding a liquid-protein supplement with low-to medium quality hay affects hay waste and cow performance. Prof. Anim. Sci. 29:552-558.

Waller, J. C. and T. Klopfenstein. 1975. Hydroxides for treating crop residues. J. Anim. Sci. 41: 424. (Abstr.).

Wanapat, M., S. Polyorach, and A. Cherthong. 2009. Effects of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows. Live Sci. 125:238-243.

Watson, A. K., J. C. Macdonald, G. E. Erickson, P. J. Kononoff, and T. J Klopfenstein. 2015. Forages and pasture symposium: optimizing the use of fibrous residues in beef and dairy diets. J. Anim. Sci. 93:2616–2625.

Wells, R., and D. Lalman. 2011. Hay Feeder Design can Reduce Hay Waste and Cost. Ag News and Views. Available from: http://www.noble.org/ag/livestock/hay-feeder-design/. (Accessed 13 April 2016).

Whitlow, L. H., S. P. Marshall, H. H. Van Horn, and J. R. Flores. 1976. Liquid feed passage route into stomach compartments, influence of abomasal infusions on plasma glucose, and supplementation of dry rations with liquid feeds from a lick-wheel feeders. J. Dairy Sci. 9:258-261.

Winterholler, S. J., D. L. Lalman, M. D. Hudson, C. E. Ward, C. R.Krehbiel, and G. W. Horn. 2008. Performance, carcass characteristics, and economic analysis of calf-fed and wheat pasture yearling systems in the southern Great Plains. Prof. Anim. Sci. 24:232–238.